Ethnicity/Race, Sex and Physical Activity: Supporting Physical Activity from Childhood to Adulthood in Diverse Populations

A Dissertation
SUBMITTED TO THE FACULTY OF THE GRADUATE SCHOOL
UNIVERSITY OF MINNESOTA
BY

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IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

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JULY 2017

Acknowledgements

While I could not have completed this work without the help of so many people, all errors, omissions or oversights in this work are mine and mine alone.

The inspiration for and a large part of this work came from the Loppet Foundation. With nearly 15 years of promoting physical activity during all seasons of the Minnesota year, the Loppet Foundation has come to be a leader not just in health promotion, but also in social justice and equity. I owe special thanks to John Munger, Allie Rykken, Margaret Adelsman, Anthony Taylor and Mike Erickson. In particular, John, Allie and Margaret all have contributed substantially over the years to the development of the Minne-Loppet Curriculum.

The Loppet Foundation has benefitted immensely from its partnership with Minneapolis Public Schools, and I am very grateful for the support of the staff and administration of MPS. I have received great support especially from Nancy Duwenhoegger, Julie Ellingson and Jennifer Stecker. The kids on my ski team were a constant source of inspiration.

This work owes a great deal to the decades of scientific work done by Dianne Neumark-Sztainer and the Project-EAT team, including Daheia Barr-Anderson, Jerica Berge, Marla Eisenberg, Peter Hannan, Katie Loth, Rich Maclehose and Melanie Wall. I have benefitted immensely from suggestions from the Project-EAT team and particularly from Nicole Larson, who was my guide through the nuances of the immense database and complex methods that have been developed over nearly twenty years of Project-EAT.

So much of the support I have had for this work comes from my family. My parents – Wes and Nancy – met in the Mayo Building. Nancy's work in community physical activity promotion and Wes' 40 year career with the University of Minnesota Medical School were the inspiration for my entrance into Public Health. My idiot brothers, Matt and Nick, provided diversions when I was getting too serious with my studies, as did Franz. Unending thanks are due to my amazing wife Naomi, who is my motivation and comfort and has been my excellent example of starting a career.

Particular thanks to my committee: Melissa Laska, Toben Nelson and Julian Wolfson. Their insights and comments were crucial to this work. Finally, I am most grateful to have had such a superb mentor and advisor as Mark Pereira to guide me through the last five years.

Dedication

This work is inspired by a problem I encountered as a program coach for the Loppet Foundation. In this role, I was trying to promote physical activity through biking and skiing among racially and socioeconomically diverse elementary and middle school students. I observed very quickly that these sports drew in more boys than girls. What was more surprising was that race and sex seemed to play a combined role. I had a great deal of success recruiting and retaining African-American boys and Hispanic girls, less success with Hispanic boys and virtually no success with African American girls. This led me to wonder how motivation to be physically active is differently determined not just by race and sex separately, but specifically within unique subgroups determined by race and sex together. This work is, therefore, dedicated to all Loppet Foundation team members past, present and future.

Abstract

Interventions to increase population physical activity are often conducted in diverse populations, particularly in schools. Understanding differences in intervention effects and determinants of physical activity across population subgroups should help improve the effectiveness of interventions. We examined how an intervention effect and determinants of physical activity differ by or are consistent across ethnicities/races and the sexes. In the first manuscript, we estimated the effect of the Minne-Loppet Ski Program, an elementary school cross-country ski intervention, on motivation to exercise and tested whether effects differ by ethnicities/race or sex. Motivation to ski increased among Minne-Loppet Ski program participants compared to students in control classrooms. Motivation to *exercise* increased among African American and white participants but not Hispanic participants. In the second manuscript, we used cross-sectional data from Project EAT-2010 to test a social-ecological model of determinants of physical activity. Determinants clustered into eight factors. A factor that included personal and social determinants had the strongest association with physical activity. In the third manuscript, we used cross-sectional data from Project EAT-2010 to estimate differences in personal, social and environmental determinants of physical activity across ethnicities/races and the sexes in middle and high school students. Most determinants of physical activity did not vary by ethnicity/race. Among females, neighborhood road connectivity, distance to trails and perceived mother's physical activity differed in their associations with physical activity by ethnicity/race. Among males home media equipment and sports participation differed in their associations with physical activity by ethnicity/race. In the fourth manuscript we used longitudinal data from Project EAT-I

through EAT-IV to estimate differences in trajectories of physical activity and its determinants across ethnicities/races and the sexes in middle and high school students. Declines in physical activity happened later among males than among females. Only the association of BMI with physical activity differed by ethnicity/race and sex. The results from these analyses show that there is a great deal of consistency in the determinants of physical activity across ethnicities/races, but differences that emerge should be considered when implementing future physical activity interventions.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

BMI – Body Mass Index
CATCH – Child and Adolescent Trial for Cardiovascular Health
CFA – Confirmatory Factor Analysis
EFA – Exploratory Factor Analysis
FDR – False Discovery Rate
GEE – Generalized Estimating Equations
GIS – Geographic Information Systems
ICC – Intraclass Correlation Coefficient
IRB – Institutional Review Board
LCA – Latent Class Analysis
MDES – Minimum Detectable Effect Size
MPS – Minneapolis Public Schools
MVPA – Moderate to Vigorous Physical Activity
PA – Physical Activity
PE – Physical Education
REA – Research, Evaluation and Assessment
SDT – Self-Determination Theory
SEM – Structural Equation Model
SES – Socioeconomic Status
TAAG - Trial of Activity for Adolescent Girls

Chapter 1. Background

Aims

Designing physical activity interventions for schools and communities is challenging because of the diverse motivations for and barriers to physical activity (PA). Among Americans, 40% of children achieve the recommended level of 60 minutes of moderate to vigorous physical activity (MVPA) per day. This proportion falls to 8% among adolescents and only 5% of adults manage 30 minutes per day of physical activity.[1] Lack of physical activity is linked to obesity, heart disease, cancer and other diseases.[2] Because physical activity decreases with age and is consistently lower in girls than in boys, work has been done to understand how the determinants of physical activity vary with age and between the sexes. It is less clear how the determinants of physical activity vary between ethnicities and races. Less clear still is how determinants of physical activity vary between, or are consistent across, population subgroups defined by ethnicity/race and sex. To design interventions to increase levels of physical activity that will be successful in diverse settings like schools, it is crucial to better understand how determinants of physical activity vary between, or are consistent across, subgroups within the population.

Interventions to increase physical activity in children and adolescents are often implemented in schools, recreation centers or parks. But even within one school or one community center, there can be a broad diversity of people. In one Minneapolis Public School, for instance, there may by Hmong, Somali, African-American, white and Hispanic students, all of whom may have different motivations to be physically active. Interventions that do not take into account the diversity of the population may not be

effective for all children within the school or community center. Therefore, the focus of this study is first to describe the evaluation of an ongoing physical activity intervention among grade school children, including how the effects of the intervention differ between, or are consistent across, ethnic and racial groups and between the sexes. Second, this study will use observational data to further identify determinants of physical activity that differ between, or are consistent across, ethnicities/races and the sexes. Data for the analyses in this study come from The Loppet Foundation's Minne-Loppet Ski Program – a physical activity intervention in Minneapolis Public Schools that aims to increase motivation to be active by teaching cross country skiing to elementary school students, and from Project EAT, a longitudinal cohort study of public school students in the Twin Cities of Minnesota. The specific aims of this study are:

Aim 1: Test the effect of the Minne-Loppet Ski Program on motivation to exercise and determine whether the effect of the Minne-Loppet Ski Program intervention varies by ethnicity/race and sex?

Aim 2: Identify determinants of physical activity that vary by ethnicity/race and sex, and that are consistent across ethnicity/race and sex, in the Project EAT cohort of adolescents from the Twin Cities.

Aim 1 will be addressed in the first manuscript presented in this study. Aim 2 will be addressed in the second, third and fourth manuscripts presented in this study. This study is unique because there are relatively few studies that compare the difference in physical activity intervention effects, or the relative strength of different determinants of physical activity, between both sexes and multiple races from the same geographical area. The results of this study

will be directly useful in refining the interventions offered by the Loppet Foundation. There will also be a broader significance for these results. By examining the role of race and sex in determining physical activity behavior, we will expand the understanding of determinants of physical activity, which will be useful for developing future interventions that need to reach many groups within the same setting.

Theoretical Model

This study is grounded in a social-ecological approach to health behavior.[3] Specifically, the theoretical model for this study is composed of three parts: a framework, model and several theories. The framework and model are at a high level and provide a visual representation of the general connections expected between the determinants physical activity and actual physical activity behavior. The theories nested within the framework are finer-grained and propose more specific mechanisms for the development and maintenance of physical activity.

Framework

The social-ecological framework proposes that factors at different ecological levels influence health behaviors, including personal, social and environmental levels. For example, a student's choice to ride a bicycle for fun after school will be influenced by the student's motivation to be physically active at the personal level, the support of the student's family – possibly in the form of providing a bike to ride – at the interpersonal level, and at the neighborhood level the availability of a safe route to ride the bike to school, among other factors.

Physical activity behavior has previously been described within the social-ecological framework[3,4]. First, Sallis et al[3,4] divided physical activity into 4 domains – recreation,

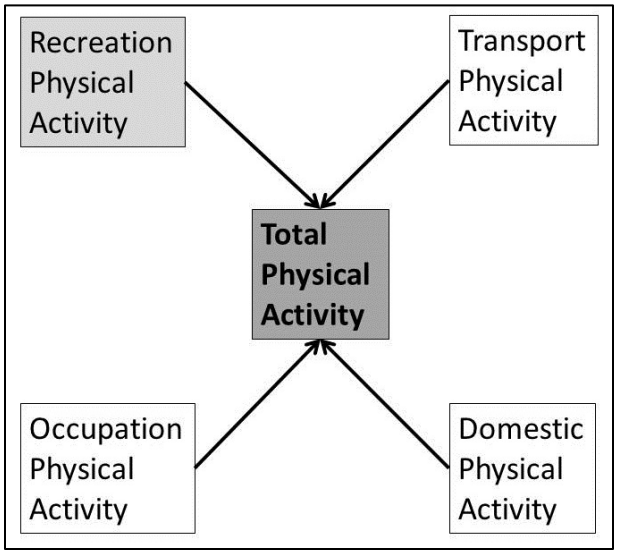

Figure 1: Domains of Physical Activity

occupational, transport and domestic (Figure 1). Occupation and domestic physical activity are activities performed as a part of work or home duties. A mail carrier walking their delivery route would be engaged in occupation physical activity. A teenager mowing their lawn would be engaged in domestic physical activity. Transport physical activity is activity performed in order to get from one place to another. A downtown office worker biking into work would be engaged in transport physical activity. Recreation physical activity is activity performed for enjoyment during free-time. An example of recreation physical activity is cross-country skiing for exercise after school.

Next, Sallis et al[3] proposed that the determinants of each of these domains are different, though many determinants are relevant to multiple domains. While it may be of interest to consider the overlaps in determinants among domains, the current work is focused on recreation physical activity.

Model

While the social-ecological framework is useful for organizing levels of influence on health behaviors, it is quite general. More specific models and theories nested in this framework allow testable hypotheses. The

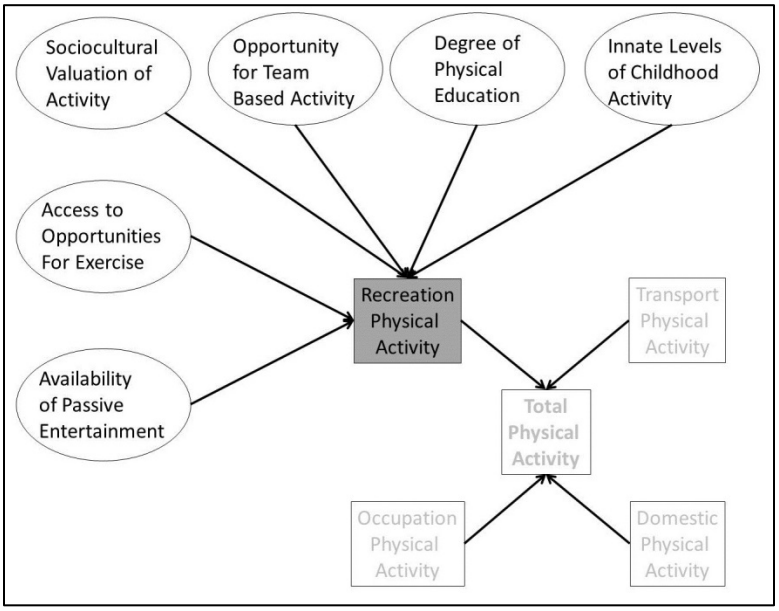

Figure 2: Core Determinants of Recreation Physical Activity

British Government Office for Science's Project Foresight organized determinants of obesity, including physical activity, into a complex systems model.[5] While we do not intend to examine the entire model, we have extracted the physical activity component of the model to organize the determinants of recreation physical activity. The core determinants of recreation physical activity under the Project Foresight model reflect the personal, social and environmental levels of the social-ecological framework (Figure 2).

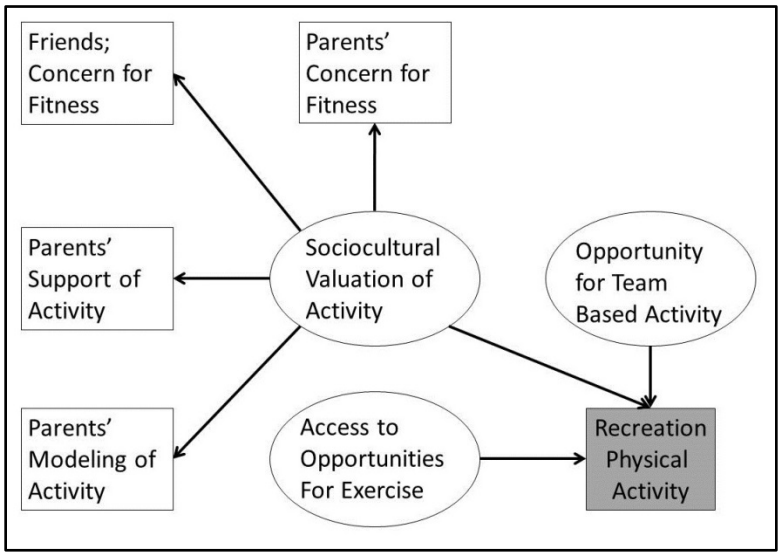

Figure 3: Observed variables mapped onto sociocultural valuation of activity

However, the titles of these determinants indicate that most will be difficult, if not impossible to measure precisely. Many of the constructs remain somewhat vague. For example, does access to opportunities for exercise mean perceived or actual opportunities? What proportion of this access is determined by natural environment factors like weather or topography as opposed to built-environment factors like proximity to parks or bike paths? Because of this vagueness, these determinants are nearly impossible to observe directly, and may need to be considered latent variables. Latent variables are variables that are not directly observable but are estimated from the correlations among several observed variables accounting for measurement error. In diagrams, arrows will conventionally point from the latent variable to the observed variables (as in Figure 3).

The latent variable aspect of the theoretical model will be examined as a part of Aim 2, where we consider how determinants of physical activity may vary by, or remain consistent across, ethnicity/race and sex. The Project EAT cohort surveys used for Aim 2 measure many variables that we expect will map onto the latent determinants of physical activity proposed by the Project Foresight model. These measured variables will be shown and described in greater detail in the methods below. An example of measured variables mapping onto a latent variable is our expectation that variables measured in Project-EAT - parent support for activity, parent modeling of activity, parent concern for fitness and friend concern for fitness – will map onto the sociocultural valuation of activity latent determinant of physical activity proposed by the Project Foresight model (Figure 3).

The Project Foresight model and the social-ecological framework are useful for organizing levels of influence on health behaviors like physical activity. However, more specific theories are needed to propose testable *mechanisms* that describe how these determinants actually cause behavior change.[6] Understanding mechanisms will be particularly useful in interventions like the Minne-Loppet Ski Program where teachers and coaches are trying to influence behavior change. The Minne-Loppet Ski Program intervention part of this study is therefore grounded in Self-Determination Theory,[7] which makes specific predictions about the development of motivation to be physically active.

Theory

Self-Determination Theory proposes that motivation for health behaviors exist on a continuum from external motivation to intrinsic motivation. In the case of physical activity, a student who experiences external motivation may state that they are active because their gym teacher makes them. A student who experiences intrinsic motivation would say they are physically active purely because they enjoy it. Most people exist somewhere between these two endpoints. As people move toward intrinsic motivation, the behavior should become more self-sustaining. According to Self Determination theory, a behavior that fulfills the needs for relatedness, competence and autonomy will engender intrinsic motivation.

Relatedness is the need to identify with and feel accepted by other people. Examples of this are the communities of people that gather around particular modes of exercise. In the Twin Cities, for example, there is a community of cross-country ski racers and many events where this community can gather and fulfill the need for relatedness.

Competence is the need to feel that we are good at something. For example, becoming a skilled cross-country skier requires a great deal of practice. A person may begin cross-country skiing as a way to spend more time with their friends to meet their need for relatedness. In the process, the person may become a very skilled or competent skier. Once they have become competent, then skiing becomes an expression of that competence and the person will be more likely to ski on their own.

Autonomy is the need to be able to act independently. If competence is an expression of pride in our skill, autonomy is an expression of joy in our freedom. To continue the ski example, a middle school student may join a ski team to be with their friends, fulfilling the need for relatedness. In the process they become a skilled skier and skiing becomes an expression of their pride in this skill, fulfilling the need for competence. Finally they realize that the skis allow them to better explore their world: they can be outside during the winter, exploring woods and mountains, fulfilling the need for autonomy.

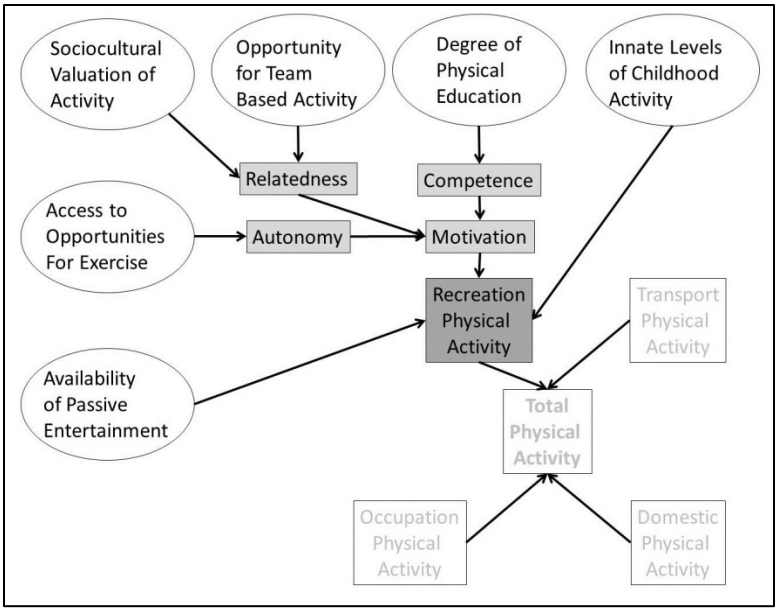

Figure 4: Self-Determination Theory

When relatedness, competence and autonomy work in concert, it moves people towards intrinsic motivation. The usefulness of Self-Determination Theory is that it proposes a mechanism for how the forces within a person come together to produce motivation, which will sustain a health behavior. Nesting Self-Determination Theory within the Project Foresight model and the social-ecological framework, we consider these variables – competence, relatedness and autonomy to be intermediate between the latent Project Foresight determinants and physical activity. We expect that sociocultural valuation of activity and opportunity for team-based activity will increase physical

activity by increasing feelings of relatedness. We expect that degree of physical education will increase physical activity by increasing feelings of competence. We expect that access to opportunities for exercise will increase physical activity by increasing feelings of autonomy (Figure 4).

The Minne-Loppet intervention directly affects degree of physical education, access to opportunities for exercise and opportunities for team-based activity as described in more detail in the methods below. Because of this, we have measured relatedness, competence, autonomy and intrinsic motivation as outcomes of interest for the Minne-Loppet intervention.

We hope that by grounding this study in a social-ecological framework, the Project Foresight model and Self-Determination Theory, we will gain a better understanding of the development of physical activity as a health behavior. As described next, there is a body of literature devoted to understanding the development of physical activity, but the modifiable determinants of physical activity remain poorly understood.

Chapter 2. Literature Review

This study aims to identify determinants of physical activity vary by ethnicity/ race and sex and that are consistent across ethnicity/race and sex, because relatively few universal determinants of physical activity have been identified. Many potential determinants of physical activity have been examined among children and adolescents, but few of these have been examined in enough studies to be considered consistently and universally associated with physical activity. Age[1,8–10], sex[10–15], previous physical activity behavior[11,12,14] and physical activity self-efficacy[11–14] seem to be the most consistent determinants of physical activity (Figure 5). Of these consistent determinants, only physical activity self-efficacy is modifiable. It is possible that modifiable determinants of physical activity act differently among different population subgroups, particularly with regards to the strength of their effect. For instance, body image may be a strong determinant of physical activity among white teenage girls, but not a strong determinant of physical activity among African American adult women. Different strengths of determinants between population subgroups could explain the lack of universal consistency in determinants of physical activity.

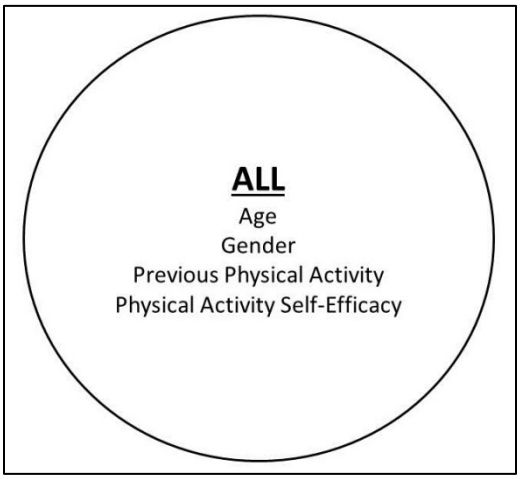

Figure 5: Consistent Determinants of Physical Activity

In physical activity studies, subgroup analyses are often done by age and by sex. However, we believe that determinants of physical activity may differ by other demographics as well. Therefore we will closely examine the state of the literature on

ethnic/racial determinants of physical activity. Because it seems clear that physical activity declines with age and that boys are more active than girls, many studies stratify on age and sex to examine determinants of physical activity[11,16]. Since there are more studies that examine age and sex differences in determinants of physical activity, we will first summarize this literature as described in several review articles. Then we will turn to the more complex, and less studied, task of examining the literature on the differences in determinants of physical activity by ethnicity/race.

To examine the literature on the differences in determinants of physical activity by ethnicity/race we conducted a semi-systematic review. We first identified relevant review articles on determinants of physical activity from the years 2000 to the present[10–13,16–19]. These review articles reported differences in determinants by age and gender, but not by ethnicity/race, though many of the studies reviewed in these articles did stratify on ethnicity/race. After review articles were considered, we conducted database searches to identify articles written in 2010 or later. We assumed that all potentially relevant studies prior to 2010 were identified in the review articles we examined, since most of these reviews were written before 2012. The studies we identified that stratify on ethnicity/race will be described in the section on differences in determinants by ethnicity/race. We conclude by discussing the unique contributions of the present study, given the strengths and weaknesses of the current state of the literature.

Differences in determinants by age

Many studies have examined the personal, social and environmental determinants of physical activity among children (<12 years old) and adolescents (12 – 18 years old). Several review articles summarize these differences[10–12,17–19]. While age and sex have the

biggest effects on physical activity levels, a variety of personal, social and environmental determinants also have moderate effects on physical activity[20]. A few of these determinants, particularly social and environmental determinants, have been found that are consistently different between children and adolescents. Generally, the relative number of predictors of physical activity and the complexity of influences on physical activity seems to increase between childhood and adolescence[11,13,16,18]. From this increasing complexity, some more specific differences in the social and environmental determinants of physical activity between children and adolescents seem to emerge.

Social determinants of physical activity include support, modeling, encouragement and direct help by parents, peers and significant others. The complexity of these social determinants seems to increases with age[11,18]. For children under 11, there are fewer consistent social determinants of physical activity[11], and these are predominantly perceived support from and modeling by parents[18]. For adolescents, direct help from parents, particularly transportation to organized sports, becomes a relevant determinant of physical activity in addition to perceived modeling and support[11,18]. The simpler social determinants of children's physical activity may be a function of more unstructured play among children compared to more participation in organized sports among adolescents. Indeed, participation on sports teams[11,13] is a more consistent determinant of physical activity in adolescents than in children, while time spent outside is a more consistent determinant of physical activity in children.[11] As the modes of physical activity become more complex with age, the required social supports also become more complex.

Environmental determinants of physical activity can be positive opportunities or barriers. Among both children and adolescents, land use mix and residential density – which are positive opportunities because they create more destinations and paths for active transportation – were consistently associated with greater physical activity.[19] In addition to these opportunities, barriers like traffic volume and speed were consistently negatively associated with physical activity in children[11,12,19]. While traffic concerns seem to be related to physical activity among children, neighborhood crime incidence was negatively related to physical activity in adolescents[17]. This suggests, perhaps, a shift in safety concerns from traffic accidents to being a victim of crime as children move from childhood to adolescence.

While there is still not a great deal of consistency in the determinants of physical activity when considered by age, we have added a little more clarity. In addition to age, sex, previous physical activity behavior and physical activity self-efficacy, which seem to be consistent predictors among all people, we see that parent modeling and support, safety from cars and time outside are determinants among children and that safety from violence, participation in organized sports and the related social support for sport participation are determinants among adolescents (Figure 6).

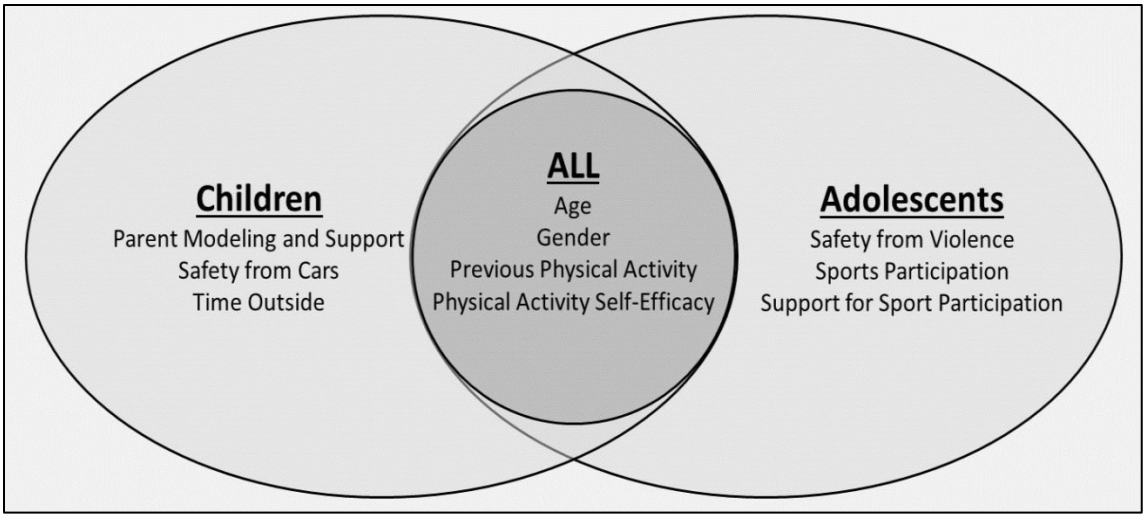

Figure 6: Determinants of Physical Activity among Children and Adolescents

Differences in determinants by sex.

The review articles considered above note that many studies stratify their analyses by sex.[11,16] However, the reviews rarely discuss exactly how determinants of physical activity differ by sex. Therefore, to examine differences in determinants of physical activity by sex, we examined studies referenced in the review articles that stratify on sex, giving particular attention to longitudinal studies and studies using objective measures of physical activity.

There is less clarity on the differences or consistencies in determinants of physical activity by sex than there is for the differences by age. This may be due to the fact that determinants studied often explain only a small part of the variation in physical activity. For instance, one study examining several determinants of physical activity only explained 12% of the variance in physical activity among boys and 5% among girls.[21] Still, as between children and adolescents, some environmental and social determinants of physical activity seem to differ between boys and girls.[15,22–25] Barriers are important determinants of physical activity in both boys and girls. But, interestingly environmental barriers like weather seem to be more important determinants of physical activity among boys,[15] while social barriers like a lack of time seem to be more important determinants of physical activity among girls.[15,26]

In addition to the differences in barriers to physical activity, there are interesting contrasts between boys and girls in the effects of access to opportunities for exercise and team based activities and availability of passive entertainment on physical activity. There is evidence that boys are more active in gym class than girls[27] and that participation in sports accounts for much of the difference in physical activity between boys and girls.[28]

By contrast, physical activity among girls, but not boys is negatively determined by television viewing.[23] Availability of passive entertainment may, therefore, be a stronger determinant of physical activity for girls than for boys, while physical activity among boys may be more determined by access to opportunities for exercise and team based activities, particularly sports participation (Figure 7).

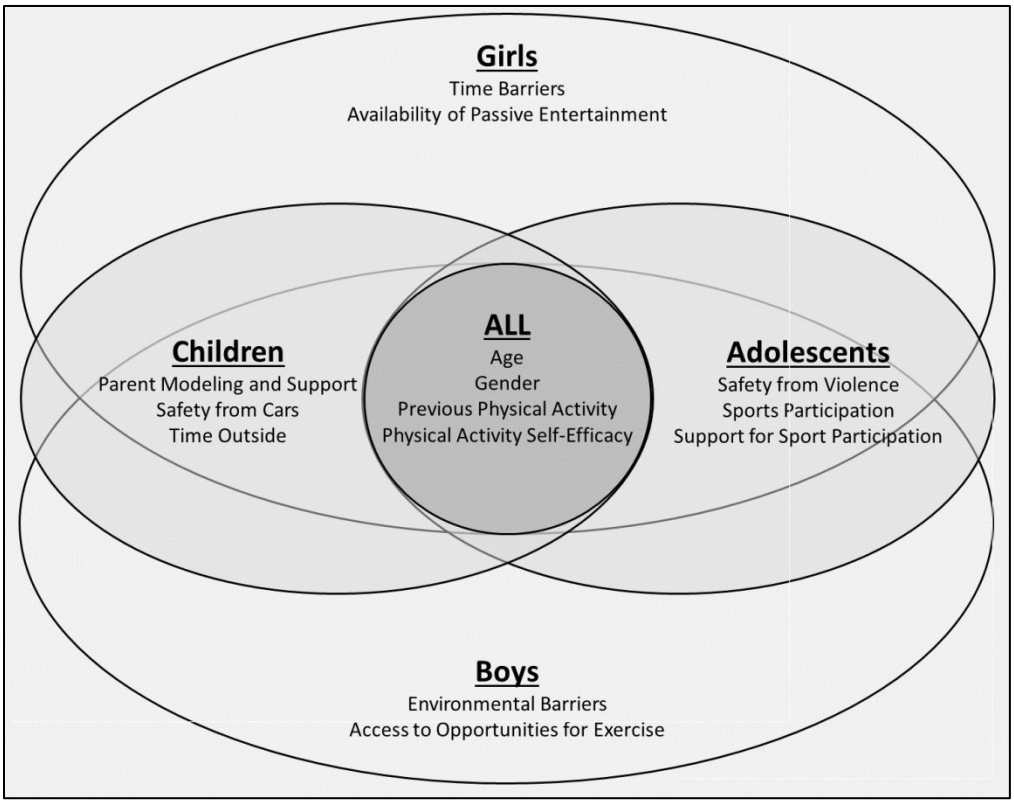

Figure 7: Differences in Determinants between Girls and Boys

Differences in determinants by race

As shown above, when examining determinants of physical activity within subgroups of the population, the picture of which determinants are relevant becomes somewhat clearer. When a demographic variable is consistently associated with physical activity, it is natural to wonder whether modifiable determinants of physical activity are consistent across, or vary between, these demographic groups. Age and sex have been

clearly linked to physical activity; therefore, many studies stratify on these demographics when searching for modifiable determinants of physical activity. There is also evidence that levels of physical activity differ by ethnicity/race.[11] However, the literature examining the differences or consistencies in determinants of physical activity between ethnicities/races is not as extensive as the literature examining differences by age or sex. For this reason we conducted a semi-systematic review of determinants of physical activity by ethnicity/race.

In April of 2016, we searched Pubmed, PsychINFO, Embase, MEDLINE, SportDiscus, CINAHL and ERIC databases for articles that included terms related to physical activity, determinants, ethnicity/race and age (Table 1). Search results were restricted to articles published after 2010. Relevant articles prior to 2010 were identified from the references in the review articles considered above.[10,11,13,14,16–19,29–33]

Table 1: Search Terms for Semi-Systematic Literature Review

AGE	OUTCOME	DETERMINANTS	RACE
child[MeSH Terms]	Physical Activity[MeSH Terms]	behavior[MeSH Terms]	race[MeSH Terms]
Adolescent[MeSH Terms	exercise[MeSH Terms]	health knowledge, attitudes, practices[MeSH Terms]	ethnicity[MeSH Terms]
child*[title]	sedentary lifestyle[MeSH Terms]	attitude to health[MeSH Terms]	ethnic groups[MeSH Terms]
adolescen*[title]	physical fitness[MeSH Terms]	social environment[MeSH Terms]	race[title]
youth[title]	Physical Activity[title]	lifestyle[MeSH Terms]	ethnic*[title]
young*[title]	exercise[title]	correlate*[title]	demograp*[title]
teenage*[title]	sedentary[title]	determinant*[title]	
	physical fitness[title]		

Our literature search yielded 851 articles from the systematic database search and 615 articles from the references of the review articles. Studies were included in this review if all the following conditions were met:

1. The sample included respondents less than 18 years old and over 4 years old. If the study was specifically done in pre-schools it was excluded.
2. The study was quantitative and used actual physical activity as the outcome (not an intermediate like physical activity intention, the study was also excluded if choice of transportation mode was the only outcome or if a measure of physical fitness like $VO2_{max}$ was the only outcome).
3. The study considered at least one *modifiable* risk factor (all studies that only examined differences in physical activity between ethnicities/races without considering how risk factors differed were excluded).
4. The study was subset or restricted by ethnicity/race (a study was considered restricted by ethnicity/race if the proportion of one ethnicity/race in the sample was 90% or above), or reported interaction terms by ethnicity/race.
5. Published in an English Language, peer-reviewed journal (dissertations were excluded).

We first reviewed titles, abstracts to determine if articles could be excluded based on the criteria above. Next, we examined methods and results to further determine which articles could be excluded. We identified 177 relevant studies – 89 from the systematic database search and 88 from the references of the review articles – that met the inclusion criteria. The 168 studies identified in the search included 118 cross-sectional studies, 28 longitudinal studies, and 31 trials.

Findings from each of these designs are considered below – beginning with trials, and then considering observational studies: cross-sectional and longitudinal. The dominant strategy of identifying determinants of physical activity effects of interventions by ethnicity/race and sex was to restrict to one ethnicity/race or one sex, which limits the ability to compare the strength of determinants of physical activity between different racial or ethnic subgroups within the same sample or geographic area. The present study of the Minne-Loppet Ski Program and the Project-EAT cohorts in the Minneapolis Metropolitan Area of Minnesota will help fill this gap in the literature.

Trials

We identified 31 trials[34–64] that estimated treatment effects within subgroups of ethnicity/race. The sample sizes in these trials ranged from 11 to 3504. Seventeen trials had fewer than 100 participants. Nine trials had 100 – 500 participants. Five trials had over 500 participants. The trials were predominantly done with Black or African American participants. Black or African American participants were included in 118 trials. Hispanic participants were included in 10 trials. White participants were included in eight trials. Asian or South Asian participants were included in two trials. Eighteen trials included children (less than 12 years old or in fifth grade or younger). Twenty-one studies included adolescents (more than 12 years old or in sixth grade or older). In 10 studies the sample was restricted to female participants. Eighteen studies included both male and female participants. Three studies did not report the proportions of the sexes in their sample.

Physical activity is assessed with self-report in 13 of these 31 trials. Three trials used parent report to measure physical activity. Fourteen trials used an objective

measures – accelerometers or pedometers – to assess physical activity. Follow up time ranged from one month to 3 years. Twenty-one trials followed participants for less than one year. Nine trials followed participants for one to three years. One trial did not report follow-up time. The designs used in these trials were also diverse. Two trials used a non-randomized, quasi-experimental group trial design. Three trials used an un-controlled pre-test, post-test design. One trial used a cross-over design. Two trials used a group-randomized design, and seven trials used a randomized-controlled design.

Among these 31 trials, we are particularly interested in trials in which unique treatment effects within subgroups defined both by ethnicity/race and by sex were estimated. There are 15 trials in which unique subgroups based on race and sex were examined. Only two trials examine multiple races and both sexes. Two trials examine multiple races but only one sex. Three trials examine one race and both sexes. Eight trials examine only one race and one sex. Table A1 in Appendix A presents the detailed results of trials in which unique groups formed by race and sex can be discerned.

Only 16 of the 31 trials[58,45,60,50,38,39,41,42,46,48,53–55,57,59,40] showed significant increases in physical activity (whether from baseline or compared to the control group). The fact that only about half of the interventions showed a significant treatment effect may be due to the small sample size in many of the trials, the short duration of many of the interventions, or the complexity of the interventions – many interventions include elements of both nutrition and physical activity. The trials that show increases in physical activity have sample sizes that range from 13 to 3504, and follow-up times ranging from one month to three years. Nine of the 16 trials showing significant

treatment effects on physical activity used either an individual randomized or a group randomized design.

The TAAG trial of Webber et al[58] is a good example of the difficulties in intervening to increase physical activity. The TAAG trial was a 36 school, multi-site group randomized trial that followed between 1700 and 3500 girls per year in a repeated cross-sectional design. The large, group-randomized TAAG trial only started to show significant treatment effects in the 3rd year. While TAAG was a well-designed trial, it was restricted to African American and White girls, making it difficult to generalize the results to males or to other ethnicities or races.

Despite the difficulties, however, the characteristics of these trials allow some recommendations. First, more trials are needed that estimate treatment effects within subgroups defined by ethnicity/race and sex to determine if interventions are universally effective. Many of the trials were undertaken with relatively small samples. Larger samples are needed to more precisely identify effects, particularly when subgroup analyses are proposed. Second, physical activity behavior may take a substantial effort to change. Interventions need to have a long duration or measure and estimate intermediate outcomes like motivation. Finally, future trials should consider findings from observational studies, some of which are described next, on which modifiable determinants could have lasting effects on physical activity behavior

Cross Sectional

We identified 118 cross-sectional studies[65–182] that estimated associations of determinants with physical activity within strata of ethnicity/race. These studies ranged in size from 25 to 91,642 participants. Three studies had fewer than 100 participants.

Fifty-six studies had 100 – 1,000 participants. Forty-six studies had 1,000 to 10000 participants. Five studies had more than 10,000 participants. Physical activity is measured by self-report in 81 of these 118 studies. Twenty-eight studies used an objective measure – accelerometer, pedometer or heart rate monitor – to assess physical activity. Three studies measured physical activity by parent-report. Two studies measured physical activity by researcher observation.

The cross-sectional studies were demographically diverse. Black or African American participants were included in 54 studies. Hispanic participants were included in 46 studies. Asian or South Asian participants were included in 31 studies. White participants were included in 58 studies. In 21 studies the sample was restricted to female participants. Ninety-seven studies included both male and female participants. Fifty-six studies included children (less than 12 years old or in fifth grade or younger). Eighty studies included adolescents (more than 12 years old or in sixth grade or older).

We were particularly interested in studies that examined determinants of physical activity within subgroups of both ethnicity/race and sex. Of the 118 cross-sectional studies that we identified that estimated associations of determinants with physical activity in strata of ethnicity/race, 59 studies additionally estimated these associations in strata of sex. The most common strategy for considering potential determinants of physical activity by ethnicity/race and sex was to restrict the sample to one race or one sex. Only 12 of the 59 studies examine multiple races and both sexes. Fifteen studies examine multiple races but only one sex. Twenty five studies examine one race and both sexes. Seven studies examine only one race and one sex. Table A2 in Appendix A presents the detailed findings of these studies.

We describe patterns of determinants of physical activity by ethnicity/race by examining determinants that are measured in multiple studies. We describe the patterns that can be discerned within Black or African American, Hispanic, Asian and White races. To describe these patterns, we identified determinants that are measured in three or more studies for each of three or more ethnicities/races.

Determinants were considered consistently positively associated (represented by a + in Table 2) if they had a positive association with physical activity in 66% or more of the studies in which they were measured. Determinants were considered consistently negatively associated (represented by a - in Table 2) if they had a negative association with physical activity in 66% or more of the studies in which they were measured. Determinants were considered consistently unassociated (represented by a 0 in Table 2) if they had no association with physical activity in 66% or more of the studies in which they were measured. The association of the determinant with physical activity was considered unclear (represented by a ? in Table 2) if less than 66% of studies showed an association in one direction or if some studies showed negative associations and some studies showed positive associations. Some determinants measured often in one race were not measured often enough in other races to estimate the consistency of their association with physical activity (represented by a . in Table 2).

The variables measured and analyzed in these cross-sectional studies were diverse. However, of the over 150 determinants for which associations with physical activity were estimated in cross-sectional analyses, only 12 determinants were analyzed in three or more studies for three or more races. These determinants were: socioeconomic status (SES)[92,131,123,142,133,160,157,147,69,112,171,100], parent

modeling[141,114,125,149,168,180,181,126,115,133,69,112,136,135,176,152,175,166,75,144,179,120], Body Mass Index (BMI)[154,71,124,178,158,133,157,112,135,144,151,99,169,66,104,170,68,130,89,118], parent support[154,123,125,168,176,175,75,144,179,99,169,66,104,68,74,108,183], self-efficacy[154,141,86,90,180,181,116,115,166,75,179,169,104,68,108,128,165], neighborhood safety[92,114,125,153,81,116,115,147,112,135,144,169,66,68,108,183,91,78,150], sedentary behavior[143,141,116,115,157,166,75,151,169,130,89,74,117,121], access to facilities[92,67,125,90,116,115,142,112,75,144,169,66,108,91,78,150], peer modeling[141,180,181,116,176,175,166,75,179], participating in PE class[92,157,112,130,83,145], barriers[125,180,181,75,144,179,99,89,183,145], and enjoyment[125,115,75,144,99,169,108,83,127].

Table 2: Variables measured in more than two studies for more than two races.

	Black or African American	Hispanic	Asian	White
Socioeconomic status (SES)	? (n = 12)	? (n = 10)	? (n = 8)	? (n = 14)
Parent Modeling	0 (n = 6)	? (n = 6)	? (n = 9)	? (n = 11)
Body Mass Index (BMI)	? (n = 11)	0 (n = 8)	0 (n = 5)	0 (n = 6)
Parent Support	? (n = 9)	0 (n = 3)	? (n = 6)	+ (n = 10)
Self-Efficacy	+ (n = 11)	+ (n = 3)	+ (n = 4)	+ (n = 10)
Neighborhood Safety	0 (n = 5)	? (n = 7)	? (n = 4)	? (n = 9)
Sedentary Behavior	? (n = 9)	? (n = 5)	.	? (n = 10)
Access to Facilities	? (n = 6)	? (n = 6)	? (n = 4)	? (n = 10)
Peer Modeling	0 (n = 3)	.	? (n = 5)	? (n = 5)
PE Class	+ (n = 3)	+ (n = 4)	.	+ (n = 3)
Barrier	.	0 (n = 4)	- (n = 3)	? (n = 5)
Enjoyment	0 (n = 5)	0 (n = 3)	.	? (n = 8)

Self-efficacy and participation in physical education (PE) class both show overall positive associations with physical activity in all races (Table 2). Other than these two, the variables were generally null or of questionable direction. Among Asian respondents, barriers were consistently negatively associated with physical activity. Parent support was consistently positively associated with physical activity only in white students.

Interestingly, body mass index (BMI) and enjoyment seemed to show null relationships with physical activity (Table 2). A few examples of findings on the association of socioeconomic status (SES) with physical activity illustrate why the null and mixed direction results were so common and why there is a need for more subgroup analyses to better understand determinants of physical activity.

In the case of SES, the findings of Bastos et al[69] and Pate et al[142] show relationships between SES and PA going in opposite directions. Bastos et al[69] studied a population of Brazilian adolescent boys and found that as a composite index of SES (based on wealth) increased, there were lower levels of physical activity. Pate et al[142] studied a population of African American and White American adolescent girls and found that as parental education increased, there were greater levels of physical activity. One of the potential explanations for this finding of opposite associations of SES with physical activity highlights the need for more subgroup analyses. There are many social and environmental differences between Brazil and America, and any of these social or environment factors could be unmeasured effect modifiers. By conducting subgroup analyses on participants from one study and one geographic area, we control many of these potential effect modifiers. By controlling potential effect modifiers, we can more closely estimate true causal effects – for example, the effect of SES on physical activity. Beyond SES, many of the determinants showing inconsistent results may be more consistent when estimated within defined subgroups, such as ethnicities/races or sexes.

Longitudinal

We identified 28 longitudinal studies[183–210] that estimated associations of determinants with physical activity in subgroups of ethnicity/race. These longitudinal

studies ranged in sizes from 168 to 10,856. Seventeen studies had 100 – 1,000 participants. Ten studies had 1,000 to 10000 participants and one study had more than 10,000 participants. Physical activity is measured by self-report in 21 of these 28 studies. Six studies used objective measurements – accelerometer or pedometer – of physical activity. One study measured physical activity by parent report. Follow up time ranged from two months to 13 years. Nine studies followed participants for less than one year. Twelve studies followed participants for one to five years. Seven studies followed participants for more than 5 years.

These longitudinal studies were less diverse than the cross sectional studies. Black or African American participants were included in nine studies. Hispanic participants were included in six studies. Asian or South Asian participants were included in seven studies. White participants were included in 20 studies. Native American participants were included in one study. Thirteen studies included children (less than 12 years old or in fifth grade or younger). Twenty-four included adolescents (more than 12 years old or in sixth grade or older). In eight studies the sample was restricted to female participants. Nineteen studies included both male and female participants. One study did not report the proportions of the sexes included.

We were particularly interested in studies that examined determinants of physical activity within subgroups of both ethnicity/race and sex. Of the 30 longitudinal studies we identified, 13 studies estimated associations of determinants with physical activity in subgroups of ethnicity/race and sex. Of these 13 studies, only two examine multiple ethnicities/races and both sexes. Six studies examine multiple ethnicities/races but only one sex. Three studies examine one ethnicity/race and both sexes. Two studies examine

only one ethnicity/race and one sex. Table A3 in Appendix A presents the detailed results for longitudinal studies in which determinants of physical activity were estimated in subgroups of ethnicity/race and sex.

To examine the consistency of determinants of physical activity between studies, we considered determinants that are measured in multiple studies (more than two) for Black or African-American, Hispanic, Asian or White participants. This was a less restrictive inclusion criterion than we used for cross-sectional studies since there are far fewer longitudinal studies. Using the more restrictive criteria we would be limited to describing one determinant (self-efficacy). Further, the stronger design of longitudinal studies allows us to put more faith in any single study than in any single cross-sectional study.

Determinants were considered consistently positively associated (represented by a + in Table 3) if they had a positive association with physical activity in 66% or more of the studies in which they were measured. Determinants were considered consistently negatively associated (represented by a - in Table 3) if they had a negative association with physical activity in 66% or more of the studies in which they were measured. Determinants were considered consistently unassociated (represented by a 0 in Table 3) if they had no association with physical activity in 66% or more of the studies in which they were measured. The association of the determinant with physical activity was considered unclear (represented by a ? in Table 3) if less than 66% of studies showed an association in one direction or if some studies showed negative associations and some studies showed positive associations. Some determinants measured often in one race were not

measured often enough in other races to estimate the consistency of their association with physical activity (represented by a . in Table 3).

Table 3: Variables measured in more than 2 studies by each race

	White	Black or African American	Hispanic	Asian
Self-Efficacy	+	+	.	+
SES	+	.	.	.
Parent Modeling	?	.	.	.
BMI	0	.	.	.
Social Support	?	+	.	.
Sedentary Behavior	?	.	.	.
Theory of Planned Behavior	+	.	.	.
Previous PA	+	+	.	.
Acculturation	.	.	?	.

White participants were most frequently included in longitudinal studies of physical activity. Of the 20 studies that included white participants, seven estimated the association of self-efficacy[195,204,192–194,200,211] with physical activity, four estimated the association of socioeconomic status (SES)[194,203,199,207] with physical activity, four estimated the association of parent-modeling[198,200,203,189] with physical activity, four estimated the association of body mass index (BMI)[194,203,199,189] with physical activity, five estimated the association of social support[195,192–194,189] with physical activity, four estimated the association of sedentary behavior[194,200,203,208] with physical activity, seven estimated the association of at least one Theory of Planned Behavior construct[195,204,194,202,197,206,203] with physical activity, and five estimated the association of previous physical activity [195,204,192,202,189] with current physical activity.

In White participants, self-efficacy, SES and previous physical activity showed a positive relationship with physical activity. Two Theory of Planned Behavior constructs

– intention[202,197,206] and perceived behavior control[204,194,197,206] – were positively and directly associated with physical activity among white participants. The Theory of Planned Behavior constructs attitude and subjective norm were less consistently directly associated with physical activity. The effect of these constructs was generally indirect and mediated by intention.[197,206] Among white participants, association of body mass index (BMI) with physical activity was, surprisingly, null. Although Kimm et al[199] showed the expected negative relationship between BMI and physical activity, the three other studies that reported BMI[194,203,189] showed no effect. The relationships for parent modeling, social support and sedentary behavior were unclear among white participants (Table 3).

Of the nine studies that included Black or African American participants, six estimated the association of self-efficacy with physical activity,[184,192–195,204] three estimated the association of previous physical activity with current physical activity,[192,195,204] and four estimated the association of social support (either parent support, peer support or general social support) with physical activity.[192–195] Each of these determinates had a positive association with physical activity (Table 3)

Of the six studies that included Hispanic participants, three estimated the association of acculturation[185,196,210] with physical activity. Acculturation showed a mixed relationship with PA, some studies showed a positive and some showed a negative association (Table 3).

Of the seven studies that included Asian participants, three estimated the association of self-efficacy[186,192,202] with physical activity. Self-efficacy showed a positive relationship with physical activity (Table 3).

Only a few determinants of physical activity could be consistently identified among ethnic and racial groups in longitudinal studies. Self-efficacy continued to be a consistent determinant of physical activity across ethnicities/races. Previous physical activity was a consistent determinant of current physical activity among Black or African American participants and white participants. While the longitudinal studies described above generally have fairly large sample size and relatively long follow up times, this review shows that relatively few longitudinal studies have included racial or ethnic minorities. Even among White participants, who have been included in more longitudinal studies, there are still not enough studies to get clarity on more than a few determinants. Therefore, more longitudinal studies are needed, particularly studies that include ethnic and racial minorities and stratify their results by race/ethnicity and sex. Stratifying on these demographics in the same sample takes advantage of the fact that many potential effect modifiers, like geographic area will be controlled. This will help create clearer picture of differences in determinants of physical activity.

Contributions of this study

This literature review shows that there is no clear picture of what determines physical activity. Determinants of physical activity may be specific to a person's social and physical environment. A clearer picture of determinants emerges as populations are considered within relevant subgroups like age and sex. There has been less work that considers how determinants differ by, or are consistent across, ethnicities/races and ethnic minorities are under-represented in studies. The number of studies that have estimated determinants of physical activity within subgroups of ethnicity/race and sex is

smaller still, and not yet extensive enough to consistently identify unique determinants within these subgroups.

Among 119 cross-sectional studies that report results by race, only 12 variables had been studied with enough frequency to compare their effects across races, but these variables often showed unclear associates. The current work will, therefore, contribute to the literature by considering multiple determinants of physical activity within subgroups defined by both race and sex from the same sample in one geographic area, thereby controlling for many potential effect modifiers.

Further, there is a need for more longitudinal studies.[6,13,17] The review of the literature only identified 28 studies that examined determinants of physical activity within subgroups of ethnicity/race, and of these only 13 examined determinants of physical activity within subgroups of both ethnicity/race and sex. Within these 13 studies, only three studies examined both sexes and more than one race. One of these three studies[209] examined differences between foreign born and non-foreign born participants (race was not explicitly used) and the other two studies compared white participants to other all other ethnic minorities.[183,207] Therefore, as far as we know, the longitudinal study reported in Manuscript 4 will be unique in estimating determinants of physical activity in unique subgroups of both sexes and multiple ethnicities/races from the same sample and geographic area.

The analysis of the Minne-Loppet Ski Program intervention in Manuscript 1 will add to the literature by joining a small handful of physical activity intervention trials that estimate treatment effects within multiple subgroups of ethnicity/race and sex. Estimating treatment effects within subgroups from the same study allows better control

of potentially unmeasured environmental and social effect modifiers, which is particularly important when it is not possible to randomly assign the treatment. Further, while the Minne-Loppet Ski Program intervention is relatively short – only 3 months – it adds to the literature by measuring motivation to exercise. We expect motivation to be an intermediate outcome that precedes actual changes in physical activity behavior. Therefore, we expect motivation to change over a shorter time period than actual physical activity behavior.

There is substantial opportunity to better understand the determinants of physical activity behavior. The lack of clarity in determinants may be partly attributable to differences of determinants between subgroups in a population. The analyses presented in this study will further our understanding of physical activity behavior by considering an intervention effect on motivation to be active and observed determinants of physical activity within unique subgroups defined by ethnicity/race and sex.

Chapter 3. Samples and Methods

This study used three cohorts of children and adolescents from public schools in the Twin Cities metropolitan area of Minnesota. We used the Minne-Loppet Motivation Study cohort to estimate an intervention effect on motivation to exercise and whether the effects differed by ethnicity/race and sex. We used the cross-sectional Project EAT-2010 cohort to estimate differences or consistencies in a large number of personal, social and environmental determinants of physical activity across ethnicity/race and sex. We used the Project EAT-I through EAT-IV cohort to estimate longitudinal differences or consistencies in a smaller number of personal and social determinants of physical activity across ethnicity/race and sex. All three cohorts are diverse on ethnicity/race and sex. By using samples from the same geographic area, this study can better control for potential effect modifiers of physical activity behavior like climate.

Sample Characteristics

The Minne-Loppet Program Intervention

The Minne-Loppet Motivation Study cohort was sampled from elementary school students participating in the Loppet Foundation's Minne-Loppet Ski Program. The Loppet Foundation is a Twin Cities community organization that promotes year-round physical activity with events and programs, especially among underserved youth on the North Side of Minneapolis. The North Side of Minneapolis has high rates of poverty and its population is predominantly African American and recent immigrants including Hispanic, Somali and Hmong and other South-East Asian ethnicities.

The Loppet Foundation is headquartered at Theodore Wirth Park: a large North Minneapolis park that has facilities for cross-country skiing, trail running, canoeing and

mountain biking. The Foundation's flagship event is the City of Lakes Loppet Ski Festival – a weekend festival of winter outdoor sports, including cross-country skiing, ice biking, speed-skating and dog sled racing. The Foundation also runs year-round outdoor sports teams at three North Minneapolis middle schools and a winter-long learn to ski curriculum in eight Twin Cities elementary schools: the Minne-Loppet Ski Program. The Minne-Loppet program began at one Minneapolis elementary school in the winter of the 2004-2005 school year. The Minne-Loppet Ski Program has since expanded to eight schools and over 730 students in the 2015-2016 school year.

The Minne-Loppet Program is an eight session cross-country ski curriculum taught by Loppet Foundation coaches to 3rd through 5th graders each winter. The program is given as a part of physical education classes in most schools and as a part of academic classes in a few schools. Each season there is a 2-3 hour meeting before the season starts where new coaches are trained in the use of the curriculum. A typical lesson from the curriculum includes teaching a ski-skill, playing a game related to nutrition knowledge and allowing the students time to ski independently. The current version of the curriculum was updated in 2014 to incorporate a Self-Determination Theory framework, with a ski-skill to support the need for competence, a game to support the need for relatedness and free-time to support the need for autonomy. The Minne-Loppet Ski Program begins in November each year and ends in February, when Minne-Loppet students are invited to participate in a ski event at the City of Lakes Loppet Festival.

The Minne-Loppet Motivation Survey Sample

The present study used data from the 2015-2016 Minne-Loppet Ski Program's Minne-Loppet Motivation Study survey. During the 2015-2016 season, students in five schools were given pre-test and post-test motivation surveys, to assess the Self-Determination Theory outcomes autonomy, competence, relatedness and intrinsic

motivation to exercise and to ski. The survey was approved by the IRB of the University of Minnesota and by the Research, Evaluation and Assessment (REA) division of the Minneapolis Public Schools. 540 students were surveyed at baseline in the 2015-2016 season, and 501 of these students were surveyed again after the Minne-Loppet Ski Program. These students were nested in 32 classrooms, which were the unit of treatment assignment. Of these, 321 students were from 20 classes that received the Minne-Loppet Ski Program. The remaining 219 students were from 12 classes that received physical education as usual. For some of the 219 control students physical education as usual included skiing, but not within the structure of the Minne-Loppet curriculum provided specifically by a ski coach. The 2015-2016 Minne-Loppet Motivation Study cohort represented a demographically diverse population (Table 5).

Table 4: Participant Numbers for Minne-Loppet by Treatment Status

	INTERVENTION: N (%)	**CONTROL: N (%)**
Sex		
Female	141 (44.1%)	102 (46.8%)
Male	179 (55.9%)	116 (53.2%)
Race		
Black	135 (42.9%)	73 (33.8%)
Hispanic	73 (23.2%)	52 (24.1%)
White	33 (10.5%)	28 (13.0%)
Mixed or Other	74 (23.5%)	63 (29.2%)
Grade		
3	45 (14.0%)	81 (37.0%)
4	143 (44.6%)	56 (25.6%)
5	133 (41.4%)	82 (37.4%)

Research and evaluation of the Minne-Loppet Ski Program is in its infancy. Therefore, to search for additional differences or consistencies in determinants of physical activity by ethnicity/race and sex, this study used the long running Project EAT

study cohorts. These cohorts were sampled from the same school districts as Minne-Loppet Ski Program participants. Therefore, determinants identified in the Project EAT cohorts may be useful for improving future iterations of the Minne-Loppet ski program, as well as other physical activity interventions.

The Project EAT Cohorts

Project EAT (Eating and Activity in Teens and Young Adults) is a longitudinal cohort that began in 1999 with surveys collected from 4746 diverse adolescents from 32 public middle schools and high schools in the Twin Cities of Minnesota. EAT-I refers to the data collected at baseline – in 1999. Students were given surveys at school that assessed many aspects of eating and physical activity behavior and were measured for height and weight. The original cohort assessed at EAT-I was followed for 17 years with three additional waves of data collection: EAT-II, EAT-III and EAT-IV. Though there was some variation in the questions asked at each wave, many of the items on the original student survey were assessed at each of the 4 waves, including physical activity (Table 4).

Table 5: Participant Numbers for Project EAT by Follow Up Wave

	WHITE	BLACK	HISPANIC	ASIAN	HAWAIIAN	NATIVE	MIXED
			EAT-I (2000) [n=4746]				
MALE	1206	421	152	419	15	74	63
FEMALE	1057	465	121	477	6	91	102
			EAT-II (2005) [n=2516]				
MALE	736	107	47	182	6	27	19
FEMALE	789	167	58	265	3	41	47
			EAT-III (2010) [n=2287]				
MALE	692	73	41	160	5	26	25
FEMALE	766	139	48	213	3	39	35
			EAT-IV (2015) [n=1830]				
MALE	564	64	24	98	4	17	13
FEMALE	677	90	39	170	2	29	25

In 2009-2010, a second cohort was begun at the same schools as the original EAT-I sample. The baseline dataset for this second cohort is referred to as EAT-2010. This cohort allows assessment of both secular trends and longitudinal trends, since EAT-2010 was collected concurrent to collection of EAT-III data from the original cohort. There were 2793 students in the EAT-2010 cohort. Of these participants, 1486 were female and 1307 were male. 525 students were white, 808 students were Black or African American, 472 students were Hispanic, 555 students were Asian and 424 students were Mixed or Other race.

A large set of possible determinants of physical activity were collected for EAT-2010. These included social determinants, some of which were collected from linked parent surveys. Data from parents was collected as part of the Project F-EAT: Families and Eating and Activity in Teens. Of the 2793 students from the EAT-2010 cohort, 2382 had at least one parent or guardian respond to the F-EAT survey and 1327 students had two parents or guardians respond to the F-EAT survey. The determinants measured at EAT-2010 also included many possible environmental determinants collected from surveys of school staff and administration and derived from geo-coded addresses and neighborhood level data.

Taken together the determinants measured in these three cohorts provide distinct lenses for analyzing factors influencing the development and maintenance of physical activity behavior. The Minne-Loppet Motivation Study cohort allows analysis of the development of motivation to exercise. The Project EAT-2010 cohort allows the analysis of a large number of personal, social and environmental determinants of physical activity in a cross-sectional sample. The Project EAT-I through EAT-IV cohort allows analysis

of longitudinal trajectories into young adulthood of a smaller set of determinants of physical activity.

Analyses and Variables

Manuscript 1: The Minne-Loppet Motivation Study

Manuscript 1 explored how motivation to exercise develops within the Minne-Loppet Ski Program. We hypothesized that the Minne-Loppet Ski Program intervention would increase intrinsic motivation to exercise (Figure 8). We hypothesized that the Minne-Loppet Ski Program intervention would increase feelings competence directly and strongly by teaching participants new skills in skiing (improving the degree of physical education). By increasing the opportunity for team based activity, we hypothesized that the Minne-Loppet Ski Program intervention would increase participants' feelings of relatedness. By providing ski equipment and transportation to the City of Lakes Loppet Ski Festival, which would increase participants' access to opportunities for exercise, we hypothesized that the Minne-Loppet Ski Program intervention would increase participants' feelings of autonomy.

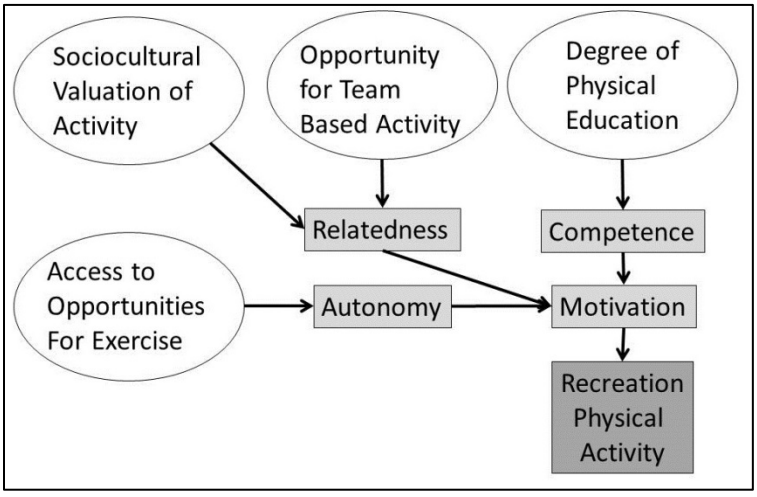

Figure 8: Minne-Loppet Model

Outcomes

The Minne-Loppet Motivation Study survey was adapted from an instrument for measuring Self-Determination Theory used by Standage et al[214]. The survey measured competence, relatedness and autonomy during physical education classes and intrinsic motivation for exercising and for skiing.

Analytic Methods

The primary goal for Manuscript 1 was to estimate treatment effects on Self-Determination Theory outcomes for the Minne-Loppet Ski Program and whether these effects differed by ethnicity/race and sex. This analysis used hierarchical linear regression to compare the change from pre-test to post test in Self-Determination Theory outcomes between the intervention group and the control group, adjusted for race, sex, and year in school, years attending the current school and baseline levels of the Self-Determination Theory variables and with a random effect for classroom. We also used hierarchical linear regression to test for differences in treatment effects of the Minne-Loppet Ski Program intervention by ethnicity/race and sex.

Manuscripts 2 and 3: Project EAT-2010

With a large sample size and many possible personal, social and environmental determinants of physical activity measured at EAT-2010, Manuscripts 2 and 3 explored how these determinants relate to physical activity within the context of the Project Foresight theoretical model described above (Figure 9), and if the associations of these determinants with physical activity differ by ethnicity/race and sex. Manuscripts 2 and 3 build on a previous study that estimated main effects for many of these Project EAT-2010 determinants with physical activity.[212] We hypothesized that determinants measured at Project EAT-2010 would map onto the latent Project Foresight determinants of physical activity (Figure 9). We also hypothesized that the determinants of physical activity would differ by ethnicity/race and sex.

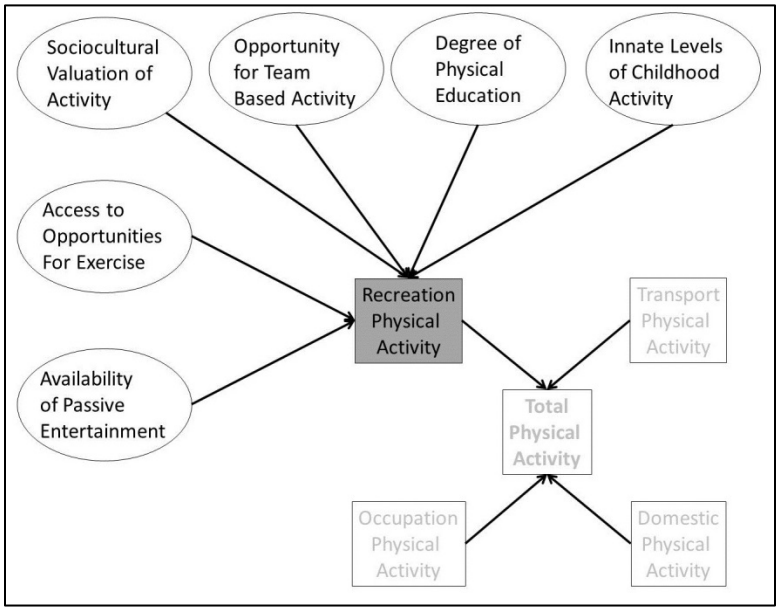

Figure 9: Core Determinants of Recreation Physical Activity

Outcome: Moderate to Vigorous Physical Activity

Moderate to Vigorous Physical Activity (MVPA) was assessed using the Godin and Shepard questions,[213] and validated with accelerometers. The Godin-Shepard questions ask about hours spent in mild, moderate or strenuous "exercise." Exercise is a subset of

recreation physical activity. While this measure may have some misclassification (for example, if respondents included active commuting in exercise); we expect that it generally reflects recreation physical activity as opposed to occupation, domestic or transportation physical activity. Weekly hours of MVPA were measured from the Godin-Shepard questions by adding the responses for moderate and strenuous exercise.

Project Foresight Constructs

Forty-six possible personal, social and environmental determinants of physical activity were measured for Project EAT-2010. We expect that these will map onto a variety of constructs from the Project Foresight model.

Innate Levels of Childhood Activity

The Project Foresight model labels one latent determinant of physical activity "innate levels of childhood activity". We have subtitled this latent variable "inclination to activity". We expected seven determinants measured in EAT-2010 to map onto "inclination to activity". These determinants are: physical activity enjoyment, physical activity barriers, physical activity self-efficacy, physical activity self-management, body mass index (BMI), past year substance use and depression (Figure 10).

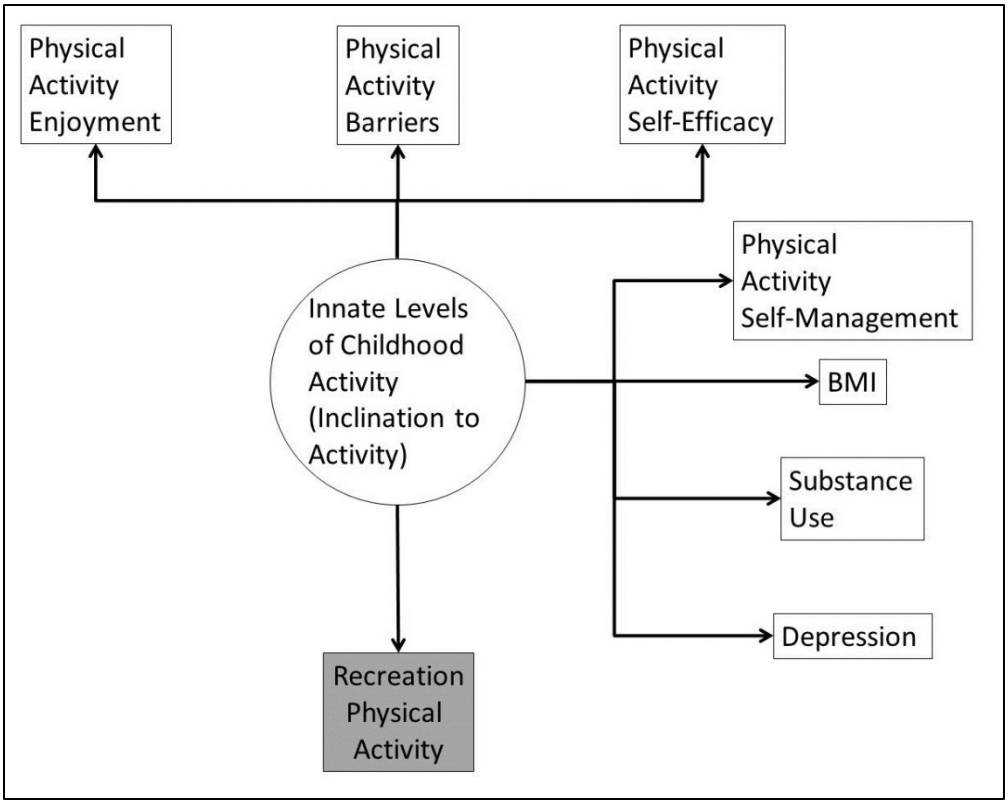

Figure 10: Observed predictors of innate levels of physical activity

Opportunity for Team Based Activity

The Project Foresight model labels one latent determinant of physical activity "opportunity for team based activity". We expected five determinants measured in EAT-2010 to map onto "opportunity for team based activity". These determinants are: school activity fees, availability of a school sport bus, distance to the nearest gym, distance to the nearest recreation center and participation on sports teams (Figure 11).

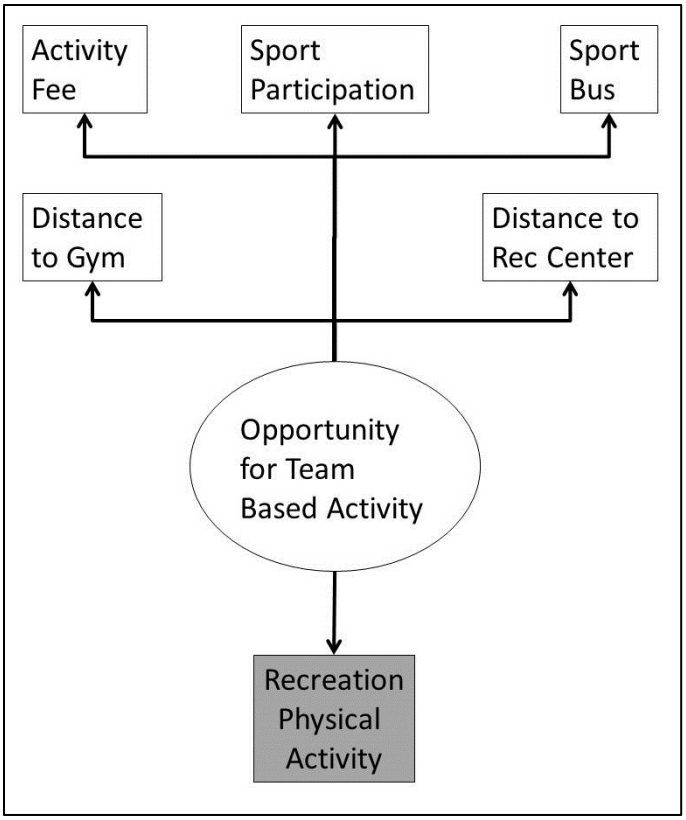

Figure 11: Measured Indicators of Opportunity for Team Activity

Access to Opportunities for Exercise

The Project Foresight model labels one latent determinant of physical activity "access to opportunities for exercise". We expected eleven determinants measured in EAT-2010 to map onto "access to opportunities for exercise". These determinants are: density of parks near home, indoor physical education facilities at school, outdoor physical education facilities at school, perceived neighborhood daytime safety, perceived neighborhood nighttime safety, busy streets in the neighborhood, distance to the nearest trail, neighborhood road connectivity, reported neighborhood crime, distance to school and home physical activity equipment (Figure 12).

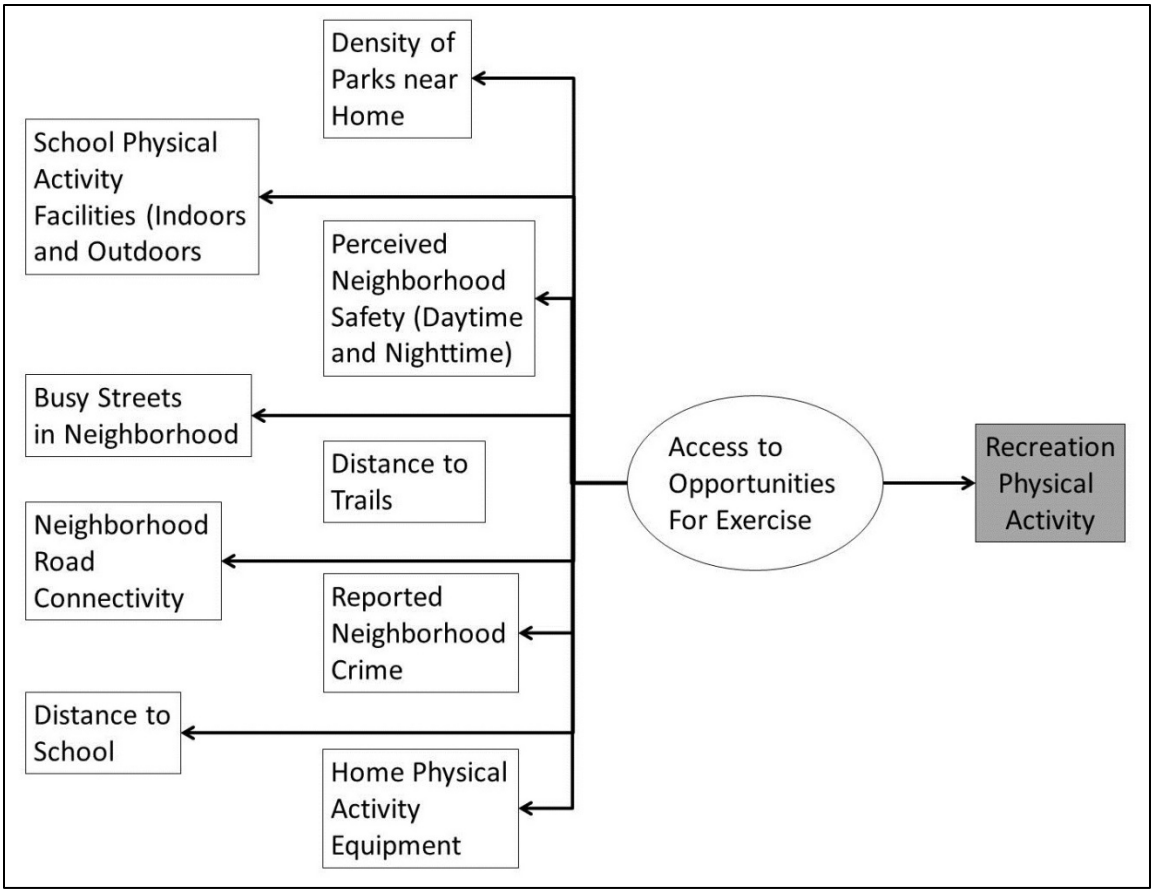

Figure 12: Measured Indicators of Opportunity for Exercise

Sociocultural Valuation of Activity

The Project Foresight model labels one latent determinant of physical activity "sociocultural valuation of activity." We have subtitled this latent variable "social norms." We expected 14 determinants measured in EAT-2010 to map onto "sociocultural valuation of activity". These determinants are: perceived mother's physical activity, perceived father's physical activity, parent self-reported physical activity, parent is active with child, family does active things, family support for physical activity, parent helps child be active, parent talks to child about being active, friends play sports, friends think it is important to be active,

friends are active together, friend self-reported physical activity, school physical activity promotion and average physical activity of students in the school (Figure 13).

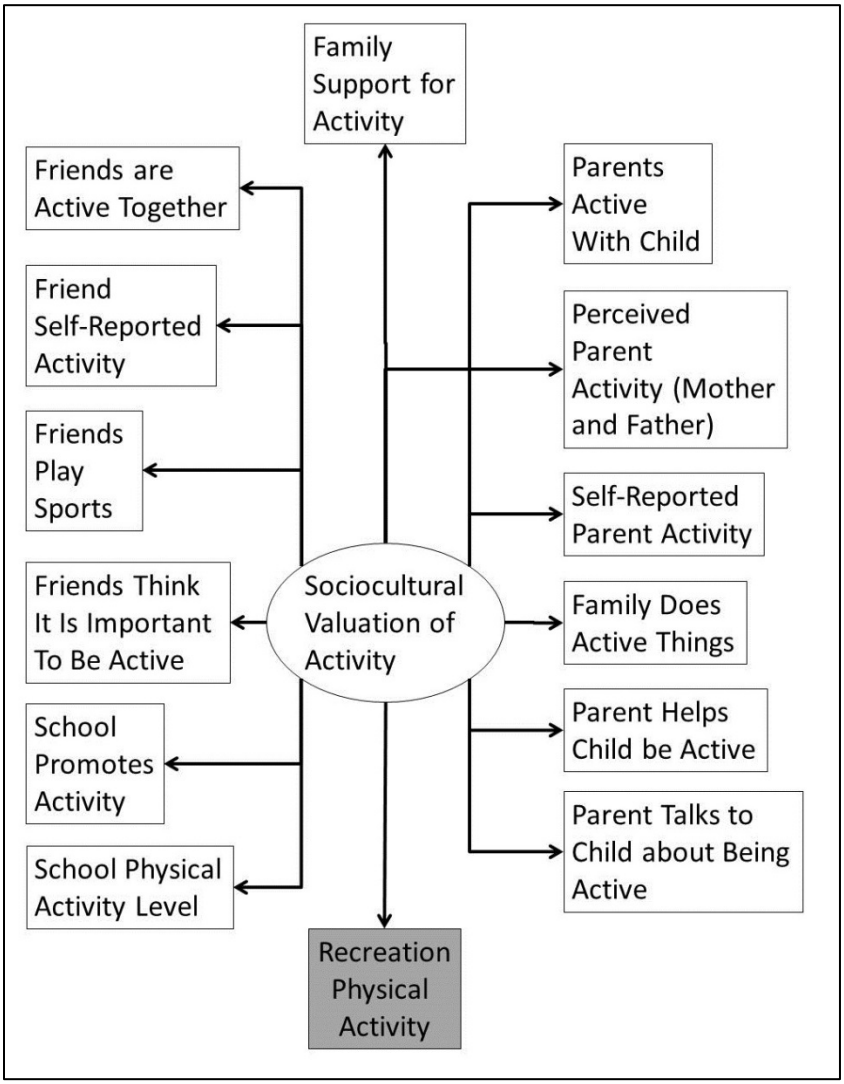

Figure 13: Measured Indicators of Sociocultural Valuation of Activity

Degree of Physical Education

The Project Foresight model labels one latent determinant of physical activity "degree of physical education". We expected four determinants measured in EAT-2010 to map onto "degree of physical education". These determinants are: 10 year change in physical

education budget, time spent in PE in an average week, school physical education credit requirement and whether the participant had gym class in the last year (Figure 14).

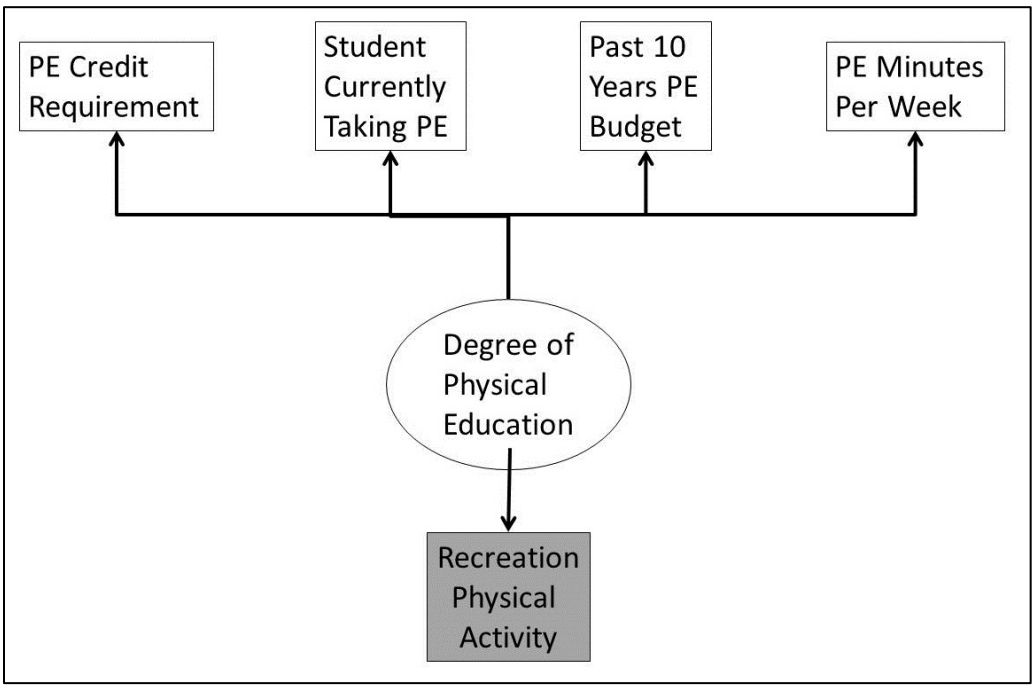

Figure 14: Measured Indicators of Degree of Physical Education

Availability of Passive Entertainment

The Project Foresight model labels one latent determinant of physical activity "availability of passive entertainment". We expected six determinants measured in EAT-2010 to map onto "availability of passive entertainment". These determinants are: video games in bedroom, TV in bedroom, hours per day of screen-time, parent watches TV with child, parent hours per week of screen-time, and home media equipment (Figure 15).

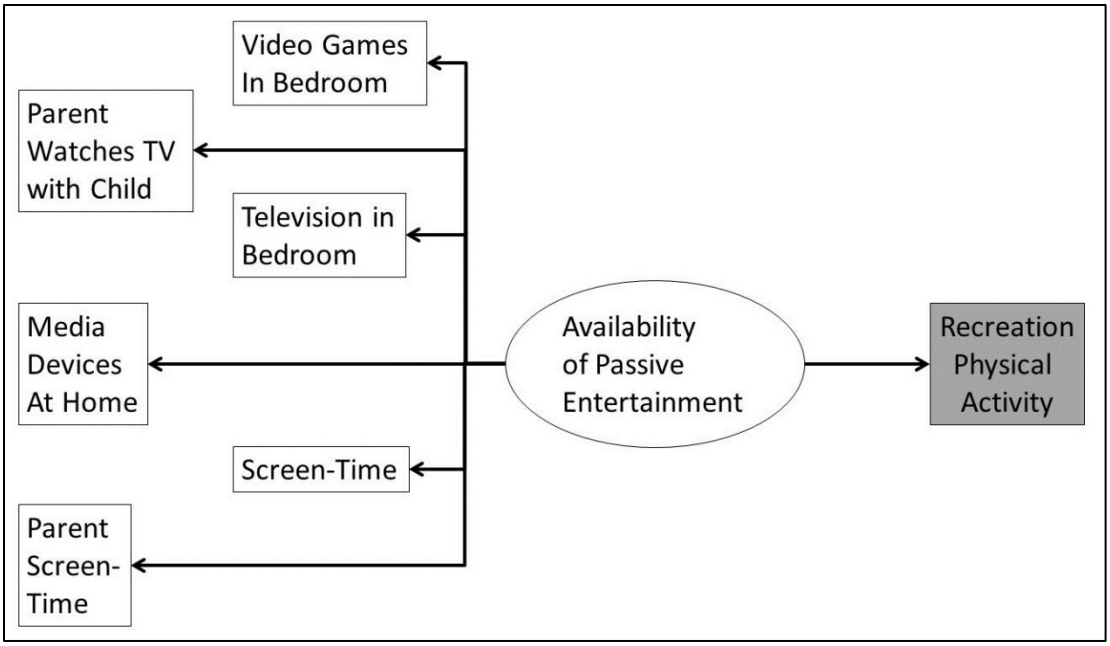

Figure 15: Measured Indicators of Passive Entertainment

Analytic Methods:

The primary goal for Manuscript 2 was to determine how well the determinants measured in Project EAT-2010 map onto the proposed Project Foresight theoretical model. This analysis used Confirmatory Factor Analysis (CFA) and Exploratory Factor Analysis (EFA) to test the mapping of measured determinants onto Project Foresight constructs. We then created scores for the latent variables identified in the factor analyses and estimated associations of these scores with MVPA using hierarchical linear regression. We tested for differences in the associations of the factor scores with MVPA by ethnicity/race and sex, also using hierarchical linear regression.

The primary goal for Manuscript 3 was to identify which measured determinants of physical activity differ by ethnicity/race and sex. This analysis used hierarchical linear regression of the determinants on MVPA and tested interactions of each determinant with

ethnicity/race and sex to determine which of the determinants differed among these demographic subgroups.

Manuscript 4: Project EAT-I through EAT-IV

Relative to EAT-2010, the sample followed over all waves of EAT-I to EAT-IV was smaller and the determinants measured at the waves of follow-up were fewer. Therefore, constrained by the determinants measured at the waves of follow-up, Manuscript 4 assessed longitudinal trends in physical activity, and estimated how these trends differed by ethnicity/race and sex. In Manuscript 4 we also estimated longitudinal determinants of physical activity and how these determinants differed by ethnicity/race and sex.

Outcome: Moderate to Vigorous Physical Activity

Moderate to Vigorous Physical Activity was assessed at baseline and each wave of follow-up using the Godin and Shepard questions[213], as described above. The Godin-Shepard questions were also validated against accelerometer measures for this cohort at EAT-III.

Independent Variables

Eight potential determinants of physical activity were included in analyses for Manuscript 4: BMI, depression, concern for fitness, substance use, perceived parental activity, friends' concern for fitness, sports participation and screen-time. While the analyses for Manuscript 4 do not test for latent variables, we organized the determinants according to the Project Foresight construct that we expected they reflect (Table 6).

Table 6: Longitudinal Determinants of Physical Activity (Manuscript 4)	
LATENT CONSTRUCT	**MEASURED VARIABLE**
Innate Levels of Activity (Inclination to Activity)	BMI Depression Concern for Fitness Substance Use
Sociocultural Valuation of Activity	Perceived Parental Activity Friends' Concern for Fitness
Opportunities for Team Based Activity	Sports Participation
Availability of Passive Entertainment	Screen-Time

Six of these determinants are modeled as time-varying: BMI, depression, concern for fitness, substance use, friends' concern for fitness and screen-time. Two of these determinants – sports participation and perceive parental activity – as modeled as baseline determinants.

Analytic methods proposed

The primary goal for Manuscript 4 was to estimate how longitudinal trends in physical activity and its associations with determinants differ by or are consistent across ethnicities/races and the sexes. This analysis used Generalized Estimating Equations (GEE) to estimate trajectories of physical activity and whether these trajectories differed by ethnicity/race and sex. Next, this analysis used GEEs to estimate longitudinal associations of the eight determinants with physical activity and test whether these associations differed by ethnicity/race and sex.

Power

Since the data for all of these cohorts were previously collected, we are constrained to the sample sizes available. Therefore, we will calculate conservative estimates of minimum detectable effect sizes (MDES) for each of the analyses based on equations for hierarchical linear regression.

Manuscript 1

For a pilot study, the Minne-Loppet survey had decent power to detect an overall effect. Using the equation for MDES with correlated observations from a group:

$$MDES = \sqrt{\frac{2(1 + (m-1) * ICC)(t_{\alpha/2} + t_{\beta})^2}{n * m}}$$

where we have 501 students in 30 classrooms, 18 classrooms receiving the intervention, taking a conservative estimate of ICC within a classroom of 0.1, and assuming an average m = 15 kids per classroom, $\alpha = 0.05$ and $\beta = 0.8$, we calculated a moderate MDES of 0.41.

Since we were also interested in effects by subgroups defined by race and sex, we calculated the MDES for the smallest subgroup used: 61 white students. Assuming this is two students per class, and using the equation:

$$MDES = \sqrt{\frac{2(1 + (m-1) * ICC)(t_{\alpha/2} + t_{\beta})^2}{n * m}}$$

where m = 30 classrooms, 18 classrooms receiving the intervention, and again assuming the ICC is 0.1, $\alpha = 0.05$ and $\beta = 0.8$, we calculated a relatively large MDES of 0.76.

Manuscript 2 and 3

Since our analyses for Manuscripts 2 and 3 used subgroups defined by ethnicity/race and sex, we calculated a conservative MDES for the smallest subgroup. In the EAT-2010 sample there are 252 Hispanic males: the smallest subgroup used. Since these students were sampled from schools, there may be some inflation of the variance due to correlation of physical activity among students from the same school. To be conservative, we used the equation for MDES with correlated observations from a group:

$$MDES = \sqrt{\frac{2(1 + (m-1) * ICC)(t_{\alpha/2} + t_{\beta})^2}{n * m}}$$

The cohort included m = 20 schools. We assumed that the 216 Hispanic boys were evenly distributed among the schools and that the Intraclass Correlation Coefficient (ICC) between boys in the same school was a conservative 0.1. We assumed also that each boy had a 50% chance of meeting the criteria for the determinant modeled. From these values we estimated a MDES 0.52, a moderate effect size.

Manuscript 4

Since our analyses for Manuscript 4 used subgroups defined by ethnicity/race and sex, we calculated an MDES for the smallest subgroup we used: 83 Hispanic males. Using the equation for MDES in a repeated measures analysis:

$$MDES = \sqrt{\frac{2(1 + (m-1) * ICC)(t_{\alpha/2} + t_{\beta})^2}{n * m}}$$

where n is the sample size, m is the number of waves of follow-up and ICC is the correlation of the measures between waves of follow-up, and assuming n = 83, m = 2, α = 0.05 and β = 0.8, and each boy has a 50% chance of meeting the criteria for a

determinant, we calculated MDES for varying levels of the ICC. With an ICC of 0.1, the MDES was 0.43, a moderate effect size. With an ICC of 0.4, the MDES was still moderate at 0.49. If the ICC were as high as 0.9, the MDES for this sample size would be 0.57, a large effect size. However, given the long time between follow-ups (5 years) an ICC of 0.9 is likely to be much higher than we will actually observe.

Summary

The manuscripts that follow take several different approaches to examine determinants of physical activity by ethnicity/race and sex in children and adolescents from the same geographic area. We present the results from a quasi-experimental trial, a cross-sectional analysis of a large number of determinants of physical activity, and a longitudinal analysis of a more focused set of determinants of physical activity.

Chapter 4. Manuscript 1: The Minne-Loppet Motivation Study: An Intervention to Increase Motivation for Outdoor Winter Physical Activity in Ethnically and Racially Diverse Elementary Schools

Manuscript Abstract

Objective: A goal of physical education is to help students develop intrinsic motivation to be physically active. The purpose of this study was to test the effectiveness of an intervention to increase motivation for outdoor winter physical activity in ethnically and racially diverse third through fifth grade students.

Method: The Minne-Loppet Ski Program teaches Minneapolis area grade school students healthy physical activity and nutrition behaviors through cross-country skiing. This eight week quasi-experimental study compared Self-Determination Theory outcomes – intrinsic exercise motivation, intrinsic ski motivation, autonomy, competence and relatedness – between 291 students in 18 Minne-Loppet Ski Program classes and 210 students in 12 control classrooms from the same schools. Treatment effects were tested using hierarchical linear regression models controlled for year in school, race, sex and baseline measures of the outcomes.

Results: At post-test, Minne-Loppet program students showed significantly greater motivation to ski ($\beta = 0.95$ [0.15 to 1.75], Motivation scale ranges from 4 to 20) and significantly greater perceived competence ($\beta = 0.78$ [0.06 to 1.50], Competence scale ranges from 5 to 25) than students in control classrooms. There were significant treatment effect interactions with race for general exercise motivation and perceived competence. African American students in Minne-Loppet classes showed significantly

greater general exercise motivation (β = 1.08 [0.03 to 2.14]) and perceived competence (β = 1.95 [0.91 to 2.99]) than African American students in control classes.

Conclusions

The Minne-Loppet program promoted perceived competence and motivation to ski. Future improvements to the Minne-Loppet and similar physical activity interventions should seek to build *general* motivation from sport-specific motivation and to understand and provide support needed to better engage all participants.

Introduction

Physical inactivity is epidemic. Objective measures indicate that only 40% of children under 12 years old meet recommended levels of 300 minutes per week of moderate to vigorous physical activity.[1] During adolescence this proportion drops to below 10%.[1] Lack of physical activity is a direct cause of obesity and has been related to other chronic diseases including heart disease and some cancers.[2,215] Developing strategies to stop the declines in physical activity is a pressing public health concern.

Physical activity interventions among children have generally shown small effects on longer term outcomes like weight status or leisure time physical activity.[216] While many of these interventions have been organized around a social cognitive or social ecological framework,[58,217,218] this framework on its own may be too coarse to guide development of sustained health behaviors. Recent physical activity trials, particularly in the UK and Australia, have incorporated finer grained theories like Self-Determination Theory.[219–221] An advantage of incorporating Self-Determination Theory into the development and measurement of a trial is that the theory proposes intermediate markers of behavior change that can be measured and expected to show differences on shorter

time scales. However, we are unaware of any Self-Determination Theory based trials occurring in schools in the USA.

Self-Determination Theory[7] proposes a mechanism for the development of autonomous or intrinsic motivation. If a student's needs for autonomy, perceived competence and feelings of relatedness to teachers and other students are met, then Self-Determination Theory proposes that intrinsic motivation will develop. Physical education presents an opportunity to promote physical activity generally, especially in school districts where physical education classes are required. Physical education may promote sustainable increases in population physical activity over the life course if it promotes the development of intrinsic or autonomous motivation to exercise or be physically active. The Trans-Contextual Model,[222] derived from Self-Determination Theory proposes that intrinsic motivation to participate in physical education will translate into intrinsic motivation to be active outside of school time. More generally, the Trans-Contextual Model proposes that intrinsic motivation developed for an activity in one context will be associated with development of intrinsic motivation for related and more general activities (for example, intrinsic motivation for physical education will translate into broader intrinsic motivation for physical activity; see Figure 16).

In addition to organizing around finer-grained behavior theories and considering intermediate markers of behavior change, interventions may also need to consider the heterogeneity of effects between relevant population subgroups to further increase effectiveness at improving population levels of physical activity. While physical activity studies have increasingly sought diverse samples, we are aware of relatively few that have undertaken subgroup analysis within these samples. With respect to race/ethnicity

and sex, we are aware of only two trials[45,49] in which investigators considered effects within subgroups of both sexes and of more than one race/ethnicity within the same sample. Considering subgroups from the same sample allows more exchangeability on other potential environmental determinants as compared, for example, to considering the effect among a White population from New York to a Hispanic population from Los Angeles. Therefore the present study aims to evaluate a winter physical activity intervention grounded in Self-Determination theory and to consider whether the intervention effects differ between the sexes or between ethnicities/races.

In the present study we examine Self-Determination Theory outcomes from the Minne-Loppet Ski Program. Our a priori hypotheses were that students in the Minne-Loppet program would show greater increases in reported feelings of autonomy, competence and relatedness in physical education classes as well as greater increases in reported intrinsic motivation to ski and intrinsic motivation to exercise generally as compared to students in control classrooms. We also hypothesized that the effects of the Minne-Loppet program on Self-Determination Theory outcomes will differ by sex and by ethnicity/race.

Methods

Study Design

The Minne-Loppet Ski Program is a partnership between Minneapolis Public Schools, Osseo Area Schools and the Loppet Foundation to teach healthy physical activity and nutrition behaviors through cross-country skiing in the Twin Cities Metropolitan Area of Minnesota. The Loppet Foundation provides ski equipment to the schools and coaches who teach an eight week curriculum during the school day to third

through fifth grade students at several Twin Cities schools from November to February each winter. In 2015-2016, 679 students from seven Minneapolis public schools and one Osseo public school participated in the Minne-Loppet Ski Program.

Each 50 minute lesson in the Minne-Loppet curriculum includes a ski-skill, a nutrition game, and time for free skiing. The Minne-Loppet curriculum was originally developed in 2008 to include ski and nutrition lessons. In 2014 the curriculum was substantially revised and updated to fit within a Self-Determination Theory[7] framework: to build motivation to exercise and to ski by supporting students' needs to feel autonomous, competent and related. The 2014 curriculum update also changed the sedentary nutrition lesson component of the original curriculum to active nutrition games – like carbohydrate freeze tag, a game played on skis that teaches the difference between simple sugars and complex carbohydrates. The goal of changing to active nutrition games was to maximize the students' time on skis.

At the end of the eight week curriculum, the students are invited to participate in the Minne-Loppet Event. The Loppet Foundation provides transportation and equipment for all participating students. The Minne-Loppet Event is a one or two kilometer ski-race held in Minneapolis as part of the City of Lakes Loppet Ski Festival: a weekend Festival of cross-country ski races and related winter sports that attracts over 10,000 participants each year.

The Minne-Loppet Motivation Study was a quasi-experimental study conducted during the 2015 to 2016 school year in five of the eight elementary schools participating in the Minne-Loppet Ski Program. The Minneapolis Public Schools Research, Evaluation and Assessment Department approved the study for the seven participating

Minneapolis Public Schools. One school declined to participate and one school could not be assessed at baseline due to scheduling difficulties.

The primary aim of the Minne-Loppet Motivation Study was to assess the effect of the Minne-Loppet Ski Program on motivation to exercise and on motivation to ski among racially and ethnically diverse third through fifth grade students. The Minne-Loppet Motivation Study included a 34 item pre-survey and an identical post-survey of 321 students in 18 treatment classrooms and 219 students in 12 control classrooms. The decision about which classes received the Minne-Loppet Ski Program was made by teachers at each school in coordination with Loppet coaches and was primarily determined by schedule availability. Therefore it was not possible to randomly assign classes to treatment or intervention. The control classrooms were surveyed from the same schools as the treatment classrooms except in one school where all students received the Minne-Loppet Program. Students in control classrooms received normal physical education.

Surveys were administered by trained study staff during the first two weeks of the Minne-Loppet Ski Program (pre-surveys) and during the two weeks following the Minne-Loppet Event (post-survey). Classrooms were assigned to be controls or to receive the Minne-Loppet Ski Program before the surveys were given and students were aware of these assignments. All surveys were administered in either classrooms or in a gymnasium during physical education class. Students were instructed that the survey was not a test and that they should not share answers. To improve comprehension study staff read the questions aloud during each survey administration. Passive consent was obtained from the parents of all participants and active assent was obtained from all

participations prior to survey administration. All study procedures were approved by the Institutional Review Board at the University of Minnesota and by the Research, Evaluation and Assessment Department at Minneapolis Public Schools.

Demographics and Inverse Probability Weighting

Gender was self-reported by students as boy or girl. Race/ethnicity was self-reported as identifying as one or more of Black or African American, Hispanic or Latino, Asian American, American Indian or Native American, or white. Respondents who identified as Hispanic or Latino were classified as Hispanic regardless of whether they identified as any additional races. Respondents who identified as two or more non-Hispanic races were classified as mixed. Due to small sample sizes, respondents who identified as Asian American were collapsed into the mixed/other class. Students self-reported their year in school and this was checked against class lists by the investigator for accuracy. To assess stability, students were asked, "How many years have you gone to this school?"

Of the 540 students surveyed at baseline, 501 completed surveys at follow-up. This represents a 93% retention rate. The final analysis sample was, therefore, 291 students in Minne-Loppet classrooms and 210 students in control classrooms. Chi-square tests and t-tests comparing those that remained to those lost to follow-up on treatment status, demographics and scores on baseline measurements of the outcome variables showed that the group lost to follow-up differed significantly on race ($p = 0.045$), years at their current school ($p = 0.0004$) and treatment group ($p = 0.02$). Students lost to follow-up were more likely to be African-American than students who were retained (58.8% compared to 37.8%), were more likely to be from Minne-Loppet classrooms than control

classrooms (76.9% of those lost to follow-up were in Minne-Loppet classrooms compared to 58.1% of those retained), and reported 1.2 fewer years at their current school than students who were retained.

The differential missingness between the treatment groups created the possibility of selection bias in analysis. To account for this, all models were weighted using inverse probability weights. Inverse probability weights were created to represent the probability of being surveyed at follow-up as a function of race, sex, year in school, treatment group, years attending their current school and baseline measures of physical education autonomy, competence, relatedness, intrinsic motivation to exercise and intrinsic ski motivation.

Analysis Variables

Survey variables were adapted from the instrument to measure physical education Self-Determination used by Standage et al.[214] The survey was piloted in Minne-Loppet Ski Program classes during the 2014 – 2015 school year. Cronbach's alphas for the 2014-2015 piloting ranged from 0.57 for the autonomy scale to 0.89 for the ski motivation scale. Based on reliability results from the 2014 – 2015 piloting, items on the survey were updated to improve understanding of the questions among 3rd through 5th graders. A Flesch-Kincaid grade-level analysis was calculated for difficult questions using Microsoft Word. Questions were revised to decrease the grade-level of the question as much as possible without losing face-validity. For example, the prompt "When I have participated in exercise for a while, I feel pretty competent" on the 2014-2015 survey was changed to "When I have participated in exercise for a while, I feel pretty *capable*"

for the 2015-2016 survey. All items were measured on a 5 point Likert scale anchored by "Disagree" and "Agree."

Exercise Motivation

The exercise motivation score was the sum of four items beginning with the stem, "I exercise because…" An example item from the exercise motivation scale is, "I exercise because I enjoy learning new skills". This score ranged from 4 to 20 and showed adequate internal validity (Cronbach's alpha = 0.78 at pre-survey and 0.82 at post-survey).

Ski Motivation

The ski motivation score was the sum of four items identical to the exercise motivation items, but beginning with the stem "I ski because…" An example item from the ski motivation scale is, "I ski because it is exciting". This score ranged from 4 to 20 and showed good internal validity (Cronbach's alpha = 0.86 at pre-survey and 0.88 at post-survey).

Autonomy

The autonomy score was the sum of six items that assess freedom of choice during physical education class. An example item from the autonomy scale is "During PE class I have some choice in what I want to do." One item in the autonomy score was reverse coded. This score ranged from 6 to 30 (Cronbach's alpha = 0.60 at pre-survey and 0.54 at post-survey). The reverse coded item was primarily responsible for the lower internal reliability: when the reverse coded item was removed, Cronbach's alpha at the pre-survey rose to 0.73. We did *not* remove the reverse coded item from the score for analyses to be consistent with previous studies.

Competence

The competence score was the sum of five items that assess perceived competence during physical education class. An example item from the competence scale is "I am satisfied with my performance in the PE class." One item in the competence score was reverse coded. This score ranged from 5 to 25 and showed fair internal validity (Cronbach's alpha = 0.66 at pre-survey and 0.67 at post-survey). The reverse coded item was primarily responsible for the lower internal reliability: when the reverse coded item was removed, Cronbach's alpha at the pre-survey rose to 0.73. We did *not* remove the reverse coded item from the score for analyses to be consistent with previous studies.

Relatedness

The relatedness score was the sum of five items that assess relationships with other students in physical education class. An example item from the relatedness scale is "I feel valued by the other students in this PE class." This score ranged from 5 to 25 and showed adequate internal validity (Cronbach's alpha = 0.79 at pre-survey and 0.81 at post-survey).

Statistical Analysis

The Minne-Loppet arm and the control arm were compared on baseline demographic variables with chi-square tests, and on baseline levels of the Self-Determination Theory scores using crude random intercept models of treatment status on each score with a random effect for classroom. To assess clustering at the classroom and at the school levels, two unconditional random intercept (intercept only) models were run for each outcome. The first unconditional random intercept model included a random

effect for classroom; the second unconditional random intercept model included random effects for school and for classroom nested within school. Intraclass Correlation Coefficients (ICCs) were calculated from the variance components of these unconditional random intercept models.

Random intercept models were used to test the treatment effects on the Self-Determination Theory scores. One model was run for each of the five Self-Determination Theory outcomes. Each model was a regression of the Self-Determination Theory outcome on treatment status with a random effect for classroom, which was the unit of treatment assignment. Because classrooms could not be randomly assigned to treatments, all models were adjusted for race, sex, year in school, years attending the current school and the baseline level of the Self-Determination Theory variable. To test for heterogeneity of the treatment effect by sex, a two-way interaction term of treatment with sex was added to each of the models. Separately, to test for heterogeneity of the treatment effect by race/ethnicity, a two-way interaction term of treatment with race/ethnicity was added to each of the models. If interaction terms were statistically significant at $p < 0.05$, then models stratified on either race/ethnicity or on sex were run. Analyses were conducted with the Statistical Analysis System (SAS, version 9.4, 2013, SAS Institute, Cary, NC, USA).

Results

The Minne-Loppet arm and the control arm were similar on all demographic variables and baseline Self-Determination Theory scores except for year in school, intrinsic ski motivation and autonomy at baseline. The Minne-Loppet arm showed significantly greater ski motivation ($p = 0.0009$) and significantly lower autonomy ($p =$

0.03) at baseline than the control arm (Table 7). The greater ski motivation in the Minne-Loppet arm is expected given that students were aware of their classroom's assignment prior to survey administration. The Minne-Loppet arm included fewer 3rd graders (14.0% compared to 37.0%) and more 4th graders (44.6% compared to 25.6%) than the control arm (Table 7: $p_{chisq} < 0.0001$). At pre-survey there were 540 respondents. Of these, 501 also completed the post-survey (92.8% retention rate).

In unconditional random intercept models with random effects specified for school and for classroom nested within school, the Intraclass Correlation Coefficient (ICC) for school ranged from 0.008 for the competence outcome to 0.04 for the autonomy outcome. The ICC for classroom nested within school ranged from 0.03 for the relatedness outcome to 0.08 for the autonomy outcome. In unconditional random intercept modes with random effects specified only for classroom, the ICC for classroom ranged from 0.04 for the competence outcome to 0.12 for the autonomy outcome.

Treatment Effects

The Minne-Loppet arm did not differ significantly from the control arm on exercise motivation, autonomy or relatedness (Table 8). The Minne-Loppet arm showed significantly greater ski motivation at post-survey than the control arm ($\beta = 0.95$, 95% CI: 0.15 to 1.75), adjusted for race, sex, year in school, years attending their current school and baseline levels of ski motivation (Table 8). The Minne-Loppet arm also showed significantly greater physical education competence at post-survey than the control arm ($\beta = 0.78$, 95% CI: 0.06 to 1.50) adjusted for race, sex, year in school, years attending their current school and baseline levels of competence (Table 8).

Differences by Race and Sex

There were no differences in treatment effects by sex on any of the Self-Determination Theory outcomes. The treatment effect on exercise motivation (interaction p = 0.04) and on physical education competence (interaction p = 0.03) differed significantly by race/ethnicity. When stratified on race/ethnicity, there was a significant positive treatment effect on competence among African American students (β = 1.95, 95% CI: 0.91 to 2.99), but not among white or Hispanic students (Table 9). Similarly, there was a significant positive treatment effect on intrinsic motivation to exercise among African American students (β = 1.08, 95% CI: 0.03 to 2.14), but not among Hispanic students (Table 9). Among white students the treatment effect on intrinsic motivation to exercise did not reach statistical significance, but was similar in magnitude (β = 0.92, 95% CI: -2.07 to 3.91) to the treatment effect among African American students. The non-significance among white students on intrinsic motivation to exercise may be due to lower power considering the small sample size of white students in the population (n = 61).

While there was not statistical evidence of heterogeneity of treatment effects by sex, and only two of the outcomes showed heterogeneity by race, we have reported all the stratified treatment effects (Appendix B) by sex (Table B1) and by race (Table B2) for exploratory purposes.

Discussion

This study found that students in the Minne-Loppet Program showed greater changes in physical education competence and ski-specific motivation after the eight week intervention than students in the control classrooms. While no significant main

effect for general exercise motivation was observed, when the sample was stratified on race, there was a significant effect for general exercise motivation among African American students, but not among Hispanic Students. The effect for general exercise motivation among white students was roughly the same magnitude as for African American students; however the small sample size of white students limited the statistical power to detect a treatment effect. These findings provide evidence that the Minne-Loppet Program may show some effectiveness at increasing ski motivation. Future rounds of the program may benefit from incremental changes that better support other Self-Determination Theory outcomes, particularly autonomy, and from determining which incremental changes may better engage students that are showing less change in motivation over the course of the program.

While previous large multicomponent interventions, like the Child and Adolescent Trial for Cardiovascular Health (CATCH)[223] or the Trial of Activity for Adolescent Girls (TAAG),[58] have shown small effects on longer term-outcomes like BMI and general MVPA behavior[216,220,221], or required multiple year intervention durations to show an effect,[58,223]more proximal outcomes like motivation may show change in shorter trials.[220,221,224] Intervening to change motivation is important, as motivation in one context may increase motivation in other contexts and thereby create sustainable changes in physical activity behavior.[222] This study showed that the Minne-Loppet Program has had success in supporting the perceived competence as well as intrinsic ski motivation of students in the program. This is encouraging since cross country skiing is a complex activity that involves dynamic balance in gliding and coordination of both arm and leg movements. However, full support of intrinsic motivation to exercise is most likely to

occur if both relatedness and autonomy are supported as well. Particularly, theorists[222,225] identify autonomy support as first among equals in determining intrinsic motivation, and the key element for promoting the transfer of intrinsic motivation in one domain (motivation to ski) to more general domains (motivation to exercise). We have shown that the Minne-Loppet is supporting domain specific motivation (for skiing), but is not universally supporting general exercise motivation, particularly among Hispanic students. Future research will be needed to improve our understanding of how the constellation of Self-Determination Theory outcomes interact to lead from more specific motivation to more general motivation; and what characteristics of the program can be improved to better engage all students. Further, delineating the successful aspects of the program will allow the characteristics to be applied to and tested in other sports and physical activity interventions.

Suggestions for Program Improvement and Future Research

The curriculum for Minne-Loppet Ski Program is currently in its second version and this is the first version to be guided by Self-Determination Theory. There is, therefore, room to improve autonomy support. One simple way to improve autonomy support is to offer choices of activities within each lesson. For example, offering a competitive game, like soccer on skis, as well as a non-competitive challenge course where students are encouraged to improve on their own performance at their own pace could improve autonomy support by offering choices. Furthermore, this approach would meet the needs of children that are competitively inclined as well as those that are not.

A more complex way to support autonomy may involve working closely with the schools. While none of the classroom Intraclass Correlation Coefficients (ICCs) were

particularly high, the fact that the autonomy outcome had the highest ICC (0.12) could indicate classroom and school policies have some impact on the students' experience in the Minne-Loppet program. A particular example of a school policy that is of interest is school cold-weather policy. If a school is particularly cautious about letting students outside in cold weather – some schools require indoor recess if the temperature is below minus 9 degrees Celsius – the students may learn that it is not possible to safely be outside in cold weather, which may decrease their feelings of autonomy. Future work might test whether a change in schools' cold weather policies have an impact on students' levels of autonomy.

Future research should also consider the relationship between autonomy competence and relatedness. Do the three act synergistically? Is autonomy more predictive of motivation than relatedness and competence? Does one of the three need to precede the others? For example, is competence support a pre-requisite for autonomy support? As skiing is a skills intense sport, the time-frame required to develop true competence is likely longer than the follow-up of this study, particularly among children of this age. Future studies, as well as future data collection efforts with the Minne-Loppet program, should collect measures of competence and autonomy at multiple time-points on the same individuals and determine if the trend in competence truly does predict a lagged trend in autonomy.

Future research with the Minne-Loppet program will also need to improve process measurements including measures of dose delivered and dose received. Investigators have begun preliminary attempts to have Minne-Loppet program coaches fill out session logs each time they coach. Some of the items on these logs that will allow

characterization of dose delivered include whether or not there was time to present both the ski skill and the nutrition game, whether or not there was snow to ski on for the session and whether or not the class was kept inside due to the cold. Preliminary attempts have also been made to have coaches keep track of attendance at each session to characterize dose received. Other process evaluation measures that will be useful for future study will be what time of day each session was given – students may be more receptive in afternoons than mornings – and demographic characteristics of coaches.

Finally, building on the continually improving process evaluation measures, future research will be needed to determine which specific aspects of the Minne-Loppet program are responsible for improvements in motivation, whether these aspects can be applied to other sports and physical activity programs and interventions, and whether there are characteristics of the program that could be improved to better support motivation for all students – for example Hispanic students as identified in this study. Are there particular characteristics of the coaches that make them more or less effective, like their delivery style or if they are of the same ethnicity/race as the students? Would it be useful to have bilingual coaches? These lessons could be applied also to other sports – particularly since skiing is a winter activity and the lessons learned from one winter may be lost before the next. The Loppet Foundation has also developed mountain bike programs for older students – it may be useful to develop such programs for grade school students and test whether lessons learned from skiing can be propagated through the year by teaching summer sports as well. Additionally, future studies of the Minne-Loppet would benefit from considering potential effect modifiers beyond sex and ethnicity/race.

For example, future data collection might also measure BMI to determine if the program is more or less acceptable to students of different weigh statuses.

Strengths and Limitations

Because scheduling for the Minne-Loppet program is based on availability of the coaches and the classrooms, it was not possible to randomize the classrooms to receiving the Minne-Loppet program. While the assignment to the Minne-Loppet program is generally based on scheduling, it is possible that some teachers use the Minne-Loppet program as a reward for well-behaved classes. Further, since the Minne-Loppet is a popular program some teachers take other classes skiing outside of the Minne-Loppet program. This introduces the possibility that control classrooms received some level of the Minne-Loppet intervention (contamination). We addressed this limitation to the best of our ability by sampling control classrooms from the same schools as Minne-Loppet program classrooms and by adjusting all analyses for year in school, race, sex and baseline measures of all outcome variables to improve the exchangeability of control classrooms and Minne-Loppet program classrooms.

This study is also limited by the self-report nature of all the measures used. The students are aware of the purpose of the Minne-Loppet program and therefore may be more likely to report increased motivation because of a social desirability bias or demand characteristics[226,227]. Attempts were made to minimize this by explaining at each survey collection that the students would not be evaluated based on their answers. However, future data collection with the Minne-Loppet program should expand to include measures that are less susceptible to demand characteristics or social desirability – like direct observation or accelerometer measurement of actual physical activity during the lessons.

Also, future Minne-Loppet data collection should shift away from collecting the self-report measures during Minne-Loppet classes and should collect them weeks before the program begins and weeks after the program ends in a more neutral setting like a computer lab.

Another limitation is the generalizability of this study. The Minne-Loppet program was evaluated in one school district in Minnesota. It is unclear whether the program would be effective in other districts or in other states. Since this is a cross-country skiing intervention, it will not be directly transferable to areas that do not receive snowfall during the winter. However, we have suggested that future studies should identify successful characteristics of the Minne-Loppet program and test whether these characteristics can be applied in other interventions.

A substantial strength of this study was the use of Self-Determination Theory, a fine grained theory of motivation development, to inform and evaluate the curriculum. By measuring autonomy, competence and relatedness as well as motivation for exercise and motivation for skiing, we were able to generate evidence about which needs were being supported. This allowed us to suggest school policy changes and modifications to the curriculum that can improve its support of intrinsic motivation to ski and exercise, particularly by better supporting autonomy.

This study also benefitted from a diverse sample that allowed examination of the effects within subgroups. We are aware of only two physical activity intervention trials that examined treatment effects within subgroups of both sexes and more than one race[45,49]. In this study, we were able to show that the effects of the Minne-Loppet program did not differ by sex, and that competence and general motivation to exercise

seemed to be more supported in African American students and potentially white students than in Hispanic students.

Conclusions

Among Minne-Loppet participants, motivation to ski did increase significantly and general motivation to exercise increased significantly in African American participants and possibly among white participants as well. Future research should follow Minne-Loppet participants for longer time periods to determine if improvements in motivation to ski eventually result in increases in motivation to exercise, and how autonomy, competence and relatedness interact to support motivation. With longer follow-ups, physical activity behavior should also be tracked to determine if changes in motivation lead to changes in behavior, as well as reduce potential biases due to demand characteristics or social desirability. Process evaluation measures should be refined and analyzed to better understand dose delivered and dose received as well as to identify aspects of the program that can be translated to other sports and physical activity programs. The Minne-Loppet program was also successful in supporting the perceived competence of participants. Future research should examine if this is a first step in also supporting autonomy.

The Minne-Loppet program is run every year, so future implementations of the program will benefit from the findings of this study. Potential modifications include providing more opportunities for choice for participants to better support autonomy, providing coaches that match participants culturally and linguistically, and working with school to support a culture of being outdoors in the winter. Continuing improvement of the Minne-Loppet program will also benefit from being able to randomly assign these

incremental modifications. In future studies, all classrooms will be able to receive the Minne-Loppet program, with some classes randomized to an incremental modification. This approach will have the two-fold benefit of providing an intervention to all study participants and of testing only one aspect of the program at a time to determine which characteristics of the program can better engage all participants and which characteristics could be applied to other sports and physical activity interventions.

Tables

Table 7: Demographics and Baseline by Treatment

	Minne-Loppet	Control
n (%)		
Classrooms	18 (60.0%)	12 (40.0%)
Individuals	321 (59.4%)	219 (40.6%)
Year in School: n(%)[a]		
3rd	45 (14.0%)	81 (37.0%)
4th	143 (44.6%)	56 (25.6%)
5th	133 (41.4%)	82 (37.4%)
Sex and Race/Ethnicity: n(%)		
Male	179 (55.9%)	116 (53.2%)
White	22 (12.6%)	20 (17.2%)
African American	74 (42.3%)	37 (32.0%)
Hispanic	39 (22.3%)	27 (23.3%)
Mixed or Other	40 (22.9%)	32 (27.6%)
Female	141 (44.1%)	102 (46.8%)
White	11 (7.9%)	8 (8.0%)
African American	61 (43.6%)	36 (36.0%)
Hispanic	34 (24.3%)	25 (25.0%)
Mixed or Other	34 (24.3%)	31 (31.0%)
Baseline: Mean (SD)		
Exercise Motivation Score	16.8 (3.7)	16.5 (3.5)
Ski Motivation Score[a]	17.5 (3.5)	16.0 (4.5)
Autonomy Score[a]	20.8 (5.1)	22.9 (3.9)
Competence Score	20.1 (3.7)	19.9 (4.2)
Relatedness Score	19.0 (4.9)	19.2 (4.2)

[a]Minne-Loppet arm differs significantly from control arm at $p < 0.05$

Table 8: Treatment Effect Estimates on Each Self-Determination Theory Outcome

	Treatment Effect (Beta [95%CI])
Exercise Motivation[a]	0.12 [-0.73 to 0.96]
Ski Motivation[a]	0.95 [0.15 to 1.75][d]
Autonomy[b]	0.18 [-1.01 to 1.36]
Competence[c]	0.78 [0.06 to 1.50][d]
Relatedness[c]	0.64 [-0.18 to 1.46]

[a]Range of possible scores for the motivation scales are 4 to 20

[b]Range of possible scores for the autonomy scale is 6 to 30

[c]Range of possible scores for the competence and relatedness scales are 5 to 25

[d]Minne-Loppet arm differs significantly from control arm at $p < 0.05$

Table 9: Treatment Effect Estimates on Exercise Motivation and Competence Stratified by Race/Ethnicity

	White	*African American*	*Hispanic*	*Mixed/Other*
Exercise Motivation[a]	0.92 [-2.07 to 3.91]	1.08 [0.03 to 2.14][c]	-0.02 [-1.76 to 1.72]	-1.10 [-2.43 to 0.22]
Competence[b]	0.63 [-0.94 to 2.19]	1.95 [0.91 to 2.99][c]	-0.14 [-1.69 to 1.42]	-0.19 [-1.64 to 1.26]

[a]Range of possible scores for the motivation scale is 4 to 20

[b]Range of possible scores for the competence scale is 5 to 25

[c]Minne-Loppet arm differs significantly from control arm at $p < 0.05$

Figures

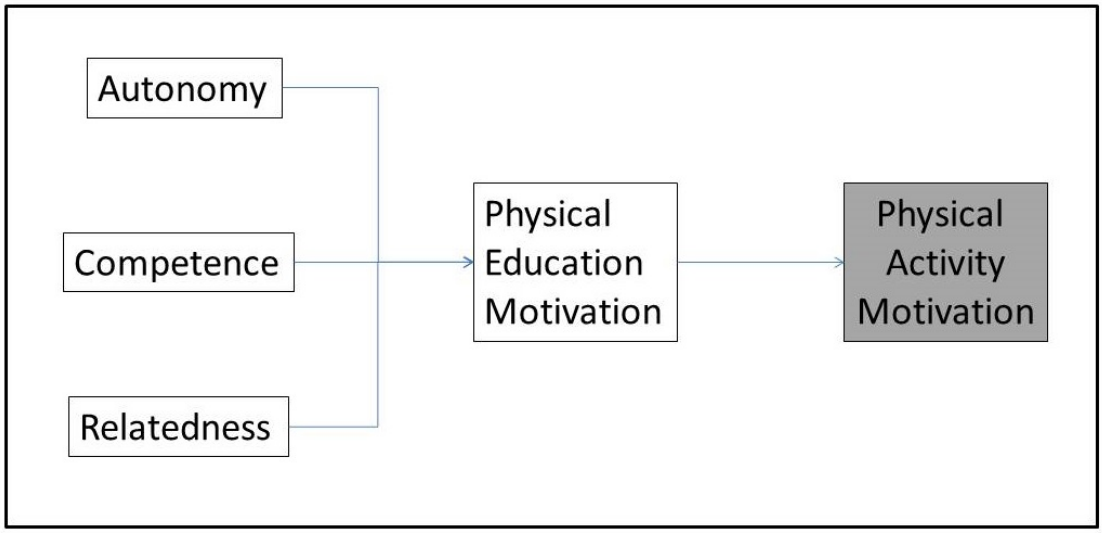

Figure 16: Development of Motivation as proposed by Self-Determination Theory

Chapter 5. Manuscript 2: A Measurement Model test for an Ecological Model of Determinants of Physical Activity Behavior in an Epidemiological Dataset using Confirmatory and Exploratory Factor Analysis.

Manuscript Abstract

Background: Studies often organize determinants of physical activity using a social-ecological framework. Yet, the fit of measured variables into models based on the social-ecological framework is rarely tested. This study examined the factor structure of determinants of moderate to vigorous physical activity (MVPA) within a hypothesized social-ecological model using factor analysis.

Methods: Forty-six personal, social and environmental determinants of physical activity behavior were measured in 2779 adolescent participants in the Project EAT-2010 study. Confirmatory factor analysis (CFA) was used to test a six factor social ecological model of these determinants. Where CFA showed inadequate fit, exploratory factor analysis (EFA) was used to empirically determine the number of factors and the loadings for each determinant. Hierarchical linear regression was used to calculate the associations of the factor scores with self-reported MVPA.

Results: The six factor model showed inadequate fit in CFA (RMSEA 90% CI: 0.072 to 0.074; CFI = 0.57). Eight factors were identified using EFA: two representing neighborhood environment determinants; two representing school environment determinants; one representing parent determinants; one representing sedentary behavior determinants; one representing personal determinants; and one representing a mix of personal and social determinants. The factor representing the mix of personal and social determinants showed the strongest association with MVPA in both males and females.

Conclusions: Although the original six factor model was not supported, the eight factor model still fits in a social-ecological framework with determinants clustering in factors at the environmental, school, social and personal levels. The factor that was most strongly correlated with MVPA represented a mix of personal and social determinants. Future work will be needed to better understand how different mechanisms for developing physical activity work within and across levels of the social-ecological framework.

Introduction

Promoting physical activity is a public health priority for preventing chronic diseases including obesity, cardiovascular disease and some cancers.[2,215] Yet, most modifiable determinants of physical activity remain poorly understood.[6] In an effort to better understand and classify determinants of physical activity, researchers often organize these determinants around a social-ecological framework.[3,4] However, most studies organize measured variables into factors based on *a priori* defined social-ecological categories.[10–12,14,212] We are aware of few previous studies that have tested how well measured variables cluster into predetermined factors or that have empirically identified clusters of measured variables related to physical activity.[228,229]

The current study aimed first to test how well measured variables from the baseline survey of a cohort study fit an *a priori* defined model based on the social-ecological framework.[5] Next, this study used exploratory modeling to empirically determine how the measured variables cluster into unique factors. Finally, this study tested the correlations of the empirically derived factors with reported weekly moderate to vigorous physical activity (MVPA) within each sex and whether these correlations differ by ethnicity/race.

Methods

Sample and Survey Development

Data for this analysis came from 2779 adolescent participants in the Project EAT-2010 (Eating and Activity in Teens) study who were not missing measurements of MVPA, ethnicity/race and sex, and from their parent's responses to the Project F-EAT (Families and Eating and Activity Among Teens) study. These coordinated surveys

assessed diet, physical activity, weight status, weight control behaviors and associated factors in adolescents. Participants' friends' responses were linked with nominations of up to six friends by each participant. Environmental data was collected from surveys of school administrators and physical education specialists, as well as from Geographic Information Systems sources based on the participants' addresses.[212,230] These studies were approved by the University of Minnesota's Institutional Review Board Human Subjects Committee.

For EAT-2010, surveys and anthropometric measures were completed by adolescents from 20 public middle schools and high schools in the Minneapolis/St. Paul metropolitan area of Minnesota during the 2009-2010 academic year. The mean age of the study population was 14.4 years (SD=2.0) and adolescents were equally divided by gender (46.9% boys, 53.1% girls; Table 10). Trained research staff measured adolescents' height and weight using standardized procedures and administered surveys during selected health, physical education, and science classes. Measurements were completed in a private area and surveys were administered during two class periods that were typically 45-50 minutes.

For Project F-EAT, data were collected by surveying up to two parents/caregivers of the adolescents in EAT-2010 about their own eating and physical activity behaviors, food-specific parenting practices, the home food environment, the home physical activity environment, the emotional atmosphere at home and the home weight culture. Approximately 30% of participants provided contact information for one parent/guardian and 70% provided information for two parents/guardians. In total, 85.3% of adolescent participants in EAT-2010 had at least one parent respond. Most parent respondents were

mothers or other female guardians (62.0%), and parents had a mean age of 42.3 years (SD=8.6). Participating families were ethnically and socioeconomically diverse. The parent sample was 29.7% white, 26.1% African American, 21.4% Asian, 17.4% Hispanic, and 5.4% mixed or other race/ethnicity. Parent surveys were collected by mail and by phone interviews.

Initial Theoretical Model

The determinants examined in this study were organized using a social-ecological framework[3,5]. The UK Government's Foresight Programme[5] is a proposed complex systems model of the development of obesity based on a social-ecological framework. Nested within this larger model is a model for the development and maintenance of physical activity (Figure 17). Variables were chosen for inclusion in this analysis based on their use in a previous study that examined non-stratified determinants of physical activity[212] or their expected relevance to the theoretical model. Measured variables from the Project EAT-2010 surveys were mapped *a priori* onto the constructs from the Foresight model to test this measurement model (Table 11).

Analysis Variables

Outcome: Moderate to Vigorous Physical Activity

Self-Reported Moderate and Vigorous Physical Activity (MVPA) was assessed using the Godin and Shepard questions.[213] These categories were converted to continuous hours using the values 0, 0.3, 1.3, 3.3, 5.3 and 8 respectively and the responses from moderate exercise and strenuous exercise were summed to get usual weekly hours of MVPA. In all models MVPA was treated as a continuous variable.

Expected Determinants:

Expected personal, social and neighborhood determinants were drawn from adolescent (EAT-2010) and parent surveys (F-EAT) as well as surveys of school administrators and physical education specialists and Geographic Information Systems measures derived from the home addresses that participants provided. These variables are grouped by the theoretical model construct they are expected to reflect and their distributional characteristics are described in Table 11.

Demographics:

Sex was self-reported by EAT-2010 participants as male or female. Ethnicity/Race was self-reported by EAT-2010 participants as one or more of: white, Black or African American, Hispanic or Latino, Asian American, Hawaiian or Pacific Islander, or American Indian or Native American. Participants who reported Hispanic or Latino ethnicity were classified as Hispanic or Latino regardless of racial identity. Non-Hispanic participants who reported two races with one race being "white" were classified as the non-white race they reported. Because of small sample sizes of Hawaiian or Pacific Islander and American Indian or Native American, these groups were included in the mixed/other race category. Age in years was calculated by subtracting the participants' birthdates from the dates the survey was administered. Parent Education was self-reported by participants' parents with categories ranging from "Did not finish high school" to "Advanced degree". Parent Education was modeled as the maximum education attained by either of the participants' parents. Income was reported by the participants' primary parent by selecting among seven categories ranging from "Less than $20,000" to "$100,000 or more". Income was modeled as a continuous variable

with a unit of $20,000 per year by assigning each category its median value and dividing by 20,000.

Statistical Analysis

Confirmatory Factor Analysis (CFA) was used to assess whether the measured variables fit the proposed Project Foresight model of MVPA. The CFA was fixed at 6 factors, one for each expected construct and estimated each factor by the measured variables expected to map to that factor (Table 11). The CFA model was accepted if the upper 90% confidence limit for the RMSEA was less than 0.05 and the Bentler CFI was greater than 0.90. To test for common source bias, correlation terms for variables measured in the same source were freed for estimation and improvements of fit on RMSEA and CFI were compared (i.e. all variables from the student EAT-2010 survey were allowed to co-vary, all variables from the parent F-EAT survey were allowed to co-vary). Where fit indices indicated that the data did not fit the hypothesized CFA model, post-hoc Exploratory Factor Analyses (EFA) were conducted to empirically determine the clustering of measured variables into factors. EFA was used first to determine the number of latent factors that best describe the data by examining the scree plot for the inflection point. Next, EFA was used to determine which items loaded onto each factor by examining geomin rotated factor loadings for the EFA model with the number of factors determined from the scree-plot. Each measured variable was assigned to the factor for which it showed the largest absolute value factor loading.

To assess the correlations of the factors with MVPA, a score for each factor for each participant was created as follows. All measured variables were coded so that the correlation expected with MVPA would be positive. Next, all measured variables were

standardized to have a mean of zero and a standard deviation of one. Next, if a participant responded to more than 75% of the variables for a given factor, the factor score was created as the mean of the standardized measured variables for that factor. To address missingness among the factor scores, a multiply imputed dataset was created with 20 imputations using the Markov Chain Monte Carlo algorithm in SAS Proc MI.

The multiply-imputed dataset was used to calculate fully adjusted hierarchical linear regression models of MVPA (standardized with mean of zero and standard deviation of one) on the factor scores. Regression coefficients and standard errors were summarized from the multiple imputations using SAS Proc MIANALYZE. These models were also adjusted for age, ethnicity/race, parent education, parent income and included a random effect for school, and run separately for males and for females. Since both the independent variables (factor scores) and the dependent variable (MVPA) were standardized to mean of zero and standard deviation of one, the estimates derived from these models can be interpreted as effect sizes. Sensitivity analyses were conducted in which variables that seemed out of place within any given factor were removed from the factor scores and fully adjusted correlations with MVPA were calculated using hierarchical linear regression.

To further test for heterogeneity of the associations by ethnicity/race, an interaction term for each factor score with ethnicity/race was calculated in hierarchical linear regression models. These tests were conducted in linear mixed models adjusted for age, parent education and parent income with a random effect specified for school. All models used the multiply imputed dataset. As ethnicity/race is a categorical variable, the test-statistics are derived from the ANOVA type-3 f-statistic for the interaction term. To

generate correct estimates of p-values from this statistic, the method of Raghunathan and Dong[231] to pool sum of square statistics in multiply imputed datasets was used. To account for the multiple tests run, we calculated the false discovery rate (FDR) for each test.[232] A lower value of FDR indicates lower probability that the discovery of a difference is in fact false. An FDR of 0.10, for example indicates that 1 in every 10 positive tests would be false-positives, or a 10% error in discovery. FDR was calculated from the table of raw p-values for the interactions of each predictor with ethnicity/race. Interaction terms with an FDR of 10% or less were considered strong evidence of an interaction. Interaction terms with an FDR of 10-20% were considered moderate evidence of an interaction. All analyses were conducted using SAS version 9.4 (2013, SAS Institute, Cary, NC, USA) and MPlus version 7.4 (2015, Los Angeles, CA, USA).

Results

Confirmatory Factor Analysis (CFA) and Exploratory Factor Analysis (EFA)

The six factor CFA model did not fit the data well (RMSEA 90% CI: 0.072 to 0.074; CFI = 0.57). Exploratory Factor Analysis showed an inflection in the scree-plot at around nine factors (Figure 18). However, when factor loadings were examined for a nine factor solution, one factor only had one measured variable loading onto it. Therefore, the eight factor solution EFA was chosen as the best fit. This solution showed fair global fit for the model (RMSEA 90% CI: 0.053 to 0.055; CFI = 0.82).

Two of the eight factors seemed to represent general environment characteristics. Two factors represented school characteristics. One school factor seemed to reflect physical education offerings and the other school factor reflected the school environment more generally. One factor captured parent physical activity behavior, and another factor

captured the participants' sedentary behaviors. One factor reflected personal level characteristics. One factor reflected a mix of personal and social characteristics (Table 12).

Correlations with MVPA

The *Personal/Social* factor showed the strongest association with MVPA among both males and females (Table 13). All other factors showed weak or non-significant associations with MVPA (Table 13). The factor score associations did not change substantially when BMI, substance use and distance to trails – all of which loaded onto unexpected factors – were removed from the models in sensitivity analyses. None of the factor scores showed even moderate evidence of differing by ethnicity/race (all FDR for the interaction terms were greater than 0.20).

Discussion

The six factor model – hypothesized from the Project Foresight theoretical model – did not fit the observations from Project EAT-2010 well when tested with Confirmatory Factor Analysis. An Exploratory Factor Analysis (EFA) showed that an eight factor model fits the Project EAT-2010 observations better. The eight factor EFA model generally fit the social ecological framework, with factors reflecting personal, parent, sedentary behavior, school and environmental determinants of MVPA. The associations of the factor scores with MVPA showed similar patterns among males and females, with the *Personal/Social* factor score most strongly associated with MVPA. None of the associations of the factor scores with MVPA differed by ethnicity/race among either sex.

Previous analyses have been undertaken of individual determinants of MVPA in the Project EAT-2010 sample as well as the relative proportion of variance explained by

determinants organized *a priori* using a social-ecological framework.[212] The present study expands on this previous work by testing whether measured variables fit into categories defined by a social-ecological framework,[5] and considering how empirically derived clusters of measured variables perform in predicting MVPA. Unlike previous analyses, the current analysis gave evidence that there may be more subtle distinctions within levels of the social-ecological framework and that some mechanisms may act across levels. Whereas Graham et al[212] analysis found that *a priori* classified personal level determinants of MVPA had the strongest direct association with MVPA, the factor we found having the strongest association with MVPA was composed of a mix of personal and social determinants.

The *Personal/Social* factor included psychological items like physical activity self-efficacy, behavioral items like participation on sports teams and social context items like perceived parent physical activity and friends' self-reported physical activity. This may reflect some level of self-sorting at adolescence into groups defined by higher or lower levels of activity and reflecting some socially and personally constructed *identity* as active or non-active. Further work will be needed both to replicate this factor in other samples and to understand the demographics of students at various points on the range of this factor.

It is possible also that within social-ecological levels there are multiple mechanisms acting at once. Ommundsen et al,[228] using EFA, found that Norwegian children primarily engaged in activity in commuting to school, in community sports and in unstructured play at school, and that the determinants of these behaviors differed. Olvera et al[229], also using EFA, found that activity among white and Hispanic children

was divided between free-play, sports, and exercise. Our study found that the environmental context and the school context were each captured by two factors in the EFA. It is possible that these factors support different modes of activity. Future work will be needed to determine if the different environmental and school factors can be replicated in different samples, and if these relate to different modes of activity, like active transportation.

Alternative Approaches, Limitations and Strengths

Latent variable approaches attempt to find clustering either of variables, or of people within categories. We chose a variable centered approach – Confirmatory and Exploratory Factor Analysis (CFA and EFA) – as opposed to a person centered approach – Latent Class Analysis (LCA). While an LCA approach to this problem would have been reasonable, our interest was in how the variables clustered and creating scores around these clusters and not classifying participants into groups. However, we recognize that many of the inferences we make from the EFA approach will be similar to those we would expect to obtain from an LCA approach.

Inferences from this study are limited by the cross-sectional nature of the data and the self-report measurement of MVPA. EAT-2010 was the cross-sectional baseline data collection from this cohort, therefore temporality cannot be established between dependent and independent variables in regression analyses and the possibility of reverse causation remains. Additionally, MVPA was assessed with self-report in this study. While self-report captures some modes of activity like swimming and contact sports that are not usually captured with accelerometers, self-report is also subject to social desirability bias. The current study also only considered MVPA as an outcome, while the

factors we identified may be more relevant, for example, to active transportation. Future studies will need to examine longitudinal data and examine other measures of MVPA like accelerometers as well as different domains of physical activity like active transport.

While the factors we identified seem to roughly fit the headings we assigned them, these headings are subjective and open to different interpretations, especially given that there are many items that load onto unexpected factors. For example, substance use loaded onto a factor with environmental determinants. Further, while we tested for residual correlation due to same source, it is possible that the factors loaded as they did in part due to questions coming from the same source. For example, the *parent* factor consisted of items only from the parent survey – including four physical activity items, but also one unexpected screen-time item. Encouragingly, though, some factors seemed very clear – like the *sedentary behavior* factor, which consisted only of home media and screen-time items and included items measured from both the adolescent surveys and the parent surveys. These factors will likely need to be refined through future work.

The strengths of this study are its breadth of measured variables and its large and diverse sample. The Project EAT-2010 sample includes measured variables at the personal, social and environmental levels of the social-ecological framework. These variables come from multiple sources, including adolescent report, parent report, surveys of school staff and neighborhood GIS measures. The breadth of variables and data sources, as well as the large sample size, allows a relatively robust testing of the Project Foresight Theoretical Measurement model. Additionally the diversity of the sample, as well as its size allowed us to perform subgroup analyses to determine if the associations of the factor scores with MVPA differed by ethnicity/race as well as by sex.

Conclusions

The social-ecological framework is useful for organizing modifiable determinants of physical activity by level of influence. However more specific mechanisms acting within each level of influence may cause determinants to further cluster within levels. And further complicating the organization of determinants is the possibility of clustering of determinants *across* social-ecological levels. The present study established that determinants of MVPA may load onto different factors within the same level of the social-ecological framework. Future work will be needed to better understand to more specific mechanisms acting on MVPA within each social-ecological level. The present study showed that a factor that captures personal and social contexts around physical activity had the strongest correlation with MVPA. Future work will be needed first to determine if this factor can be replicated in other samples, and if so what are the characteristics of individuals who score highly on this factor.

Tables

Table 10: Sample Demographics from EAT-2010	
	Analysis Sample (n = 2779)
Age: Mean (SD)	14.4 (2.0)
MVPA: Mean (SD)	5.8 (4.7)
Race-Sex Groups: n (%)	
Male	1302 (46.9%)
White	277 (10.0%)
African American	378 (13.6%)
Hispanic	252 (9.1%)
Asian	260 (9.4%)
Mixed or Other	135 (4.9%)
Female	1477 (53.1%)
White	248 (8.9%)
African American	428 (15.4%)
Hispanic	311 (11.2%)
Asian	293 (10.5%)
Mixed or Other	197 (7.1%)
Parent Education: n (%)	
Less than High School	616 (23.4%)
High School	556 (21.1%)
Some College	748 (28.4%)
Bachelor's Degree	476 (18.1%)
Advanced Degree	239 (9.1%)
Parent Income: n (%)	
Less than $20,000	846 (37.6%)
$20,000 – $34,999	516 (22.9%)
$35,000 – $49,999	351 (15.6%)
$50,000 – $74,999	266 (11.8%)
$75,000 – $99,999	137 (6.1%)
$100,000 or more	137 (6.1%)

Table 11: Determinants of MVPA by Project Foresight Model Construct

Variable (Unit)	Source	Mean (SD)	Description
Inclination to Activity			
Physical Activity Enjoyment (Range: 3-12)	Adolescent Report	5.26 (2.25)	3 item scale (Cronbach's alpha = 0.82)
Physical Activity Barriers (Range: 4-20)	Adolescent Report	9.73 (3.22)	4 item scale (Cronbach's alpha = 0.49)
Physical Activity Self-Efficacy (Range: 3-12)	Adolescent Report	7.86 (2.38)	3 item scale (Cronbach's alpha = 0.76)
Physical Activity Self-Management (Range: 5-15)	Adolescent Report	8.82 (3.14)	3 item scale (Cronbach's alpha = 0.82)
BMI (z-score)	Measured by Research Staff	0.71 (1.07)	Z-score of BMI measured as kg/m^2
Past Year Substance Use (yes/no)	Adolescent Report	3.85 (1.88)	Participant Used Alcohol, Cigarettes or Marijuana in the past year (test-retest reliability: r = 0.83)
Depression (Range: 6-18)	Adolescent Report	10.21 (3.01)	6 item scale (Cronbach's alpha = 0.83)
Opportunities for Team Based Activity			
Activity Fee (Range: 1-3)	PE Specialist Survey	2.23 (0.52)	Students must pay an activity fee to participate in any sport, intramural or physical activity clubs? (No/Waiver Available/Yes)
Availability of a Sport Bus (yes/no)	PE Specialist Survey	61% Yes	School has an afterschool bus for sports, academic, club, or discipline reasons (yes/no)
Distance to the Nearest Gym (kilometers)	GIS	1.26 (0.73)	Distance (km) to nearest gym
Distance to the nearest Rec Center (kilometers)	GIS	0.52 (0.37)	Distance (km) to nearest Rec Center
Participation on Sports Teams (count)	Adolescent Report	2.03 (1.06)	"During the past 12 months, on how many sports teams did you play?" (test-retest reliability: r = 0.86)
Opportunities for Exercise			
Density of Parks near Home (percent)	GIS	9.5 (7.4)	Percent of 1600m Buffer around home that is Greenspace
Indoor Physical Education Facilities at School (count)	PE Specialist Survey	4.55 (1.96)	Count of Indoor Activity facilities reported by PE Specialist
Outdoor Physical Education Facilities at School (count)	PE Specialist Survey	3.74 (1.36)	Count of Outdoor Activity facilities reported by PE Specialist
Perceived Neighborhood daytime safety (unsafe_day_10)	Adolescent Report	1.72 (0.9)	"The crime rate in my neighborhood makes it unsafe to go on walks during the day." (test-retest reliability: r = 0.57)

Table 11: Determinants of MVPA by Project Foresight Model Construct

Variable (Unit)	Source	Mean (SD)	Description
Perceived Neighborhood nighttime safety (unsafe_night_10)	Adolescent Report	2.29 (1.14)	"The crime rate in my neighborhood makes it unsafe to go on walks during at night." (test-retest reliability: r = 0.65)
Busy Streets in Neighborhood (count)	GIS	1.96 (0.95)	Percent of streets in 1600m Buffer around home that are busy
Distance to the nearest Trail (kilometers)	GIS	0.64 (0.47)	Street network distance (km) to nearest bike or walking trail
Neighborhood Road Connectivity (10 count of access points)	GIS	6.62 (1.67)	Count of streets crossing into 1600m buffer around home (unit= 10 crossings)
Reported Neighborhood Crime (count)	GIS	1.72 (0.97)	Count of total crimes per hectare near home in 2010
Distance to School (kilometers)	GIS	5.92 (4.58)	Street network distance (km) to school
Home Physical Activity Equipment (Range 0:5)	Parent Report	2.28 (1.37)	Parent reported count of exercise equipment available at home. (test-retest reliability: percent concordance = 80% to 89%)
Social Norms			
Perceived Mother's PA (mom_pa_10)	Adolescent Report	2.48 (0.99)	"My mother is physically active in her free time." (test-retest reliability: r= 0.70)
Perceived Father's PA (dad_pa_10)	Adolescent Report	2.54 (1.08)	"My father is physically active in his free time." (test-retest reliability: r= 0.69)
Parent Self-Reported PA (hours/week)	Parent Report	4.08 (3.7)	Parent reported moderate and vigorous physical activity (Godin-Shepard, test-retest reliability: r = 0.56 to 0.75)
Parent Active with Child (hours/week)	Parent Report	1.22 (1.53)	Hours per week parent is active with their adolescent (test-retest reliability: r = 0.58)
Family does Active Things (Range: 1-4)	Adolescent Report	2.59 (0.98)	"My family and I do active things together." (test-retest reliability: r = 0.73)
Family Support for Physical Activity (Range: 1-4)	Adolescent Report	3.14 (0.92)	"My family supports me in being physically active." (test-retest reliability: r = 0.60)
Parent helps Child be Active (hours/week)	Parent Report	1.52 (1.86)	Hours per week parent helps their adolescent be physically active (test-retest reliability: r = 0.62)
Parent Talks to Child about being Active (Range: 1-5)	Parent Report	2.97 (1.2)	"Have you had a conversation with your child about being physically active?" (test-retest reliability: r = 0.64)
Friends Play Sports (Range: 1-4)	Adolescent Report	3.18 (0.81)	"My friends often play sports or do something active." (test-retest reliability: r = 0.54)

Table 11: Determinants of MVPA by Project Foresight Model Construct

Variable (Unit)	Source	Mean (SD)	Description
Friends think it is Important to be Active (Range: 1-4)	Adolescent Report	2.91 (0.83)	"My friends think it is important to be physically active." (test-retest reliability: r = 0.43)
Friends are Active Together (Range: 1-4)	Adolescent Report	3.1 (0.87)	"My friends and I like to do active things together." (test-retest reliability: r= 0.49)
Friend Self-Reported Physical Activity (hours/week)	Adolescent Report	6.19 (3.61)	Mean of Godin Shepard self-reported MVPA among nominated friends.
School Physical Activity Promotion (Range: 1-5)	School Administrator Survey	3.49 (0.77)	"To what extent has your school made a serious effort to promote increased physical activity among students?"
Average Physical Activity of Students in School (hours/week)	Adolescent Report	5.78 (0.72)	Mean of Godin Shepard self-reported MVPA among students within the school.
Degree of PE			
10 Year change in PE budget (yes/no)	PE Specialist Survey	0.37 (0.48)	"Over the past 10 years, has there been a change in the budget for physical education equipment and supplies at this school?"
Time spent in PE in an average week (hours/week)	PE Specialist Survey	3.91 (1.5)	"On average, how many minutes per week do students at your school participate in physical education?"
School's Required Physical Education Credits (credits/year)	PE Specialist Survey	0.65 (0.58)	"What is the minimum physical education requirement for students at your school?"
Had gym class in the last year (yes/no)	Adolescent Report	47% Yes	Adolescent participated in gym class in the past year.
Passive Entertainment			
Video Games in Bedroom (yes/no)	Adolescent Report	64% Yes	In the room where you sleep, do you have an electronic games console?" (test-retest reliability: percent concordance = 94%)
TV in Bedroom (yes/no)	Adolescent Report	39% Yes	In the room where you sleep, do you have a television?" (test-retest reliability: percent concordance = 97%)
Screen Time (hours/day)	Adolescent Report	5.74 (3.82)	Hours per day watching TV, using a computer, or playing video-games. (test-retest reliability: r = 0.86)
Parent watches TV with Child (hours/week)	Parent Report	2.38 (1.92)	Hours per week parent watches TV with their adolescent (test-retest reliability: r = 0.53)
Parent TV hours (hours/week)	Parent Report	14.35	"On an average day, how many hours do you spend watching

Table 11: Determinants of MVPA by Project Foresight Model Construct			
Variable (Unit)	**Source**	**Mean (SD)**	**Description**
		(9.14)	TV, DVD's, or videos?" (test-retest reliability: r = 0.78)
Home Media Equipment (count)	Parent Report	7.75 (3.33)	Parent reported count of exercise media equipment available at home. (test-retest reliability: r = 0.73 to 0.90)

Table 12: Factor Loadings from an Eight Factor EFA for Determinants of MVPA

	Factor 1	*Factor 2*	*Factor 3*	*Factor 4*	*Factor 5*	*Factor 6*	*Factor 7*	*Factor 8*
Personal/Social								
Physical Activity Enjoyment	-0.375	0.183	-0.003	-0.026	-0.026	-0.025	0.049	0.003
Physical Activity Barriers	-0.239	0.236	-0.016	0.099	0.045	0.031	0.077	0.001
Physical Activity Self-Efficacy	0.434	0.001	0.012	0.004	0.016	-0.005	-0.009	0.087
Physical Activity Self-Management	0.458	0.104	0.019	0.038	0.048	-0.02	-0.018	0.021
Participation on Sports Teams	0.375	-0.058	0.032	-0.097	0.053	0.071	-0.012	0.024
Perceived Mother's PA	0.317	-0.134	0.197	0.136	-0.023	0.029	0.073	0.05
Perceived Father's PA	0.309	-0.07	0.156	0.142	0.004	0.103	0.083	-0.005
Family does Active Things	0.421	-0.14	0.158	0.19	-0.12	-0.011	0.01	-0.083
Family Support for Physical Activity	0.535	-0.154	0.116	0.051	-0.032	0.088	-0.02	0.009
Friends Play Sports	0.84	0.034	-0.343	-0.11	0.015	-0.021	0.002	-0.001
Friends think it is Important to be Active	0.804	0.049	-0.34	-0.003	0.03	-0.027	-0.005	-0.044
Friends are Active Together	0.737	0.014	-0.211	-0.023	-0.033	-0.033	0.034	0.023
Friend Self-Reported Physical Activity	0.136	-0.014	-0.091	-0.095	0.117	0.094	0.037	0.103
Personal 2								
BMI Percentile	-0.038	0.139	0.104	-0.078	0.016	-0.049	0.011	-0.027
Depression	-0.236	0.295	-0.014	0.023	0.115	0.004	0.029	0.076
Perceived Neighborhood daytime safety	-0.008	0.867	-0.005	0.006	-0.039	-0.003	-0.03	-0.026
Perceived Neighborhood nighttime safety	0.014	0.885	0.015	-0.018	-0.019	0.018	-0.009	-0.01
Parent								
Parent Self-Reported PA	0.013	-0.021	0.487	-0.032	0.048	-0.008	-0.018	0.055
Parent Active with Child	-0.01	0.038	0.625	-0.039	-0.009	-0.111	-0.011	-0.075
Parent helps Child be Active	0.173	0.03	0.53	-0.101	0.059	0.035	-0.017	0.05

Table 12: Factor Loadings from an Eight Factor EFA for Determinants of MVPA

	Factor 1	*Factor 2*	*Factor 3*	*Factor 4*	*Factor 5*	*Factor 6*	*Factor 7*	*Factor 8*
Parent Talks to Child about being Active	0	0.094	0.267	0.007	-0.056	-0.059	0.043	-0.089
Parent watches TV with Child	-0.049	0.051	0.319	-0.181	-0.016	-0.053	0.028	-0.029
Sedentary Behavior								
Video Games in Bedroom	-0.086	0.075	-0.009	0.786	0.061	0.016	-0.023	0.042
TV in Bedroom	-0.005	0.017	-0.031	0.899	-0.001	-0.002	0.04	0.007
Screen Time	-0.089	0.074	-0.042	-0.336	-0.01	0.015	0.031	-0.018
Parent TV hours	-0.029	0.058	0.069	-0.358	-0.039	-0.044	-0.012	0.021
Home Media Equipment	0.03	0.08	0.059	-0.328	0.013	0.088	0.059	0.259
School 1								
Sport Bus	0.036	0.066	0.034	0.076	-0.9	0.015	0.457	0.023
Indoor Physical Education Facilities at School	-0.008	0.011	0.021	0.068	0.603	0.468	-0.099	0.124
Outdoor Physical Education Facilities at School	0.041	0.029	0.054	0.109	0.708	-0.008	0.254	-0.039
Distance to the nearest Trail	-0.038	-0.01	-0.081	-0.078	-0.269	0.256	-0.014	0.044
Average Physical Activity of Students in School	0.061	0.008	0.005	0.049	0.392	0.145	0.046	0.318
Time spent in PE in an average week	-0.002	0.005	-0.016	-0.03	0.403	-0.07	-0.383	0.111
School 2								
School's Required Physical Education Credits	-0.002	-0.002	-0.015	0.066	0.186	-0.797	0.022	0.041
Had gym class in the last year	0.031	0	0.107	-0.073	-0.023	-0.211	-0.2	0.023
Activity Fee	0.005	0.021	-0.005	0.022	0.439	0.552	0.025	-0.345
Environment 1								
Substance Use	-0.068	0.02	-0.025	-0.074	0.028	0.057	-0.142	0.141
Distance to the nearest Rec Center	-0.059	-0.118	-0.06	-0.093	-0.009	0.171	0.54	0.009
Busy Streets in Neighborhood	0	-0.013	-0.004	-0.085	0.27	-0.031	0.559	-0.539
Neighborhood Road Connectivity	0.031	0.114	0.04	0.046	-0.018	0.044	-0.571	-0.404
Distance to School	0.019	0.031	-0.014	0.032	-0.018	0.102	0.451	0.138

Table 12: Factor Loadings from an Eight Factor EFA for Determinants of MVPA								
	Factor 1	*Factor 2*	*Factor 3*	*Factor 4*	*Factor 5*	*Factor 6*	*Factor 7*	*Factor 8*
School Physical Activity Promotion	0.042	0.052	0.056	0.116	-0.195	-0.126	0.478	0.245
Environment 2								
Distance to the Nearest Gym	-0.007	0.034	-0.044	0.011	0	-0.127	-0.041	0.442
Density of Parks near Home	-0.025	-0.091	0.022	-0.03	-0.009	-0.027	0.251	0.317
Reported Neighborhood Crime	0.024	0.153	0.003	0.014	-0.035	0.015	-0.145	-0.577
Home Physical Activity Equipment	0.144	-0.006	0.156	-0.129	0.01	0.104	0.066	0.217

Table 13: Associations of EFA Factor Scores with MVPA[a]

Factor	*Females: β [95% CI]*	*Males: β [95% CI]*
Personal /Social	0.76 [0.67 to 0.85]	0.85 [0.74 to 0.97]
Personal 2	-0.10 [-0.17 to -0.03]	-0.04 [-0.13 to 0.05]
Parent	0.04 [-0.04 to 0.13]	0.11 [-0.0002 to 0.22]
Sedentary	-0.06 [-0.15 to 0.03]	-0.05 [-0.14 to 0.04]
School 1	0.16 [0.06 to 0.27]	0.05 [-0.07 to 0.17]
School 2	0.12 [0.04 to 0.19]	0.001 [-0.08 to 0.08]
Environment 1	-0.12 [-0.25 to 0.01]	0.02 [-0.13 to 0.16]
Environment 2	0.04 [-0.05 to 0.13]	0.11 [0.01 to 0.21]

[a]Models mutually adjusted for all factor scores as well as age, race, parent education and parent income

Figures

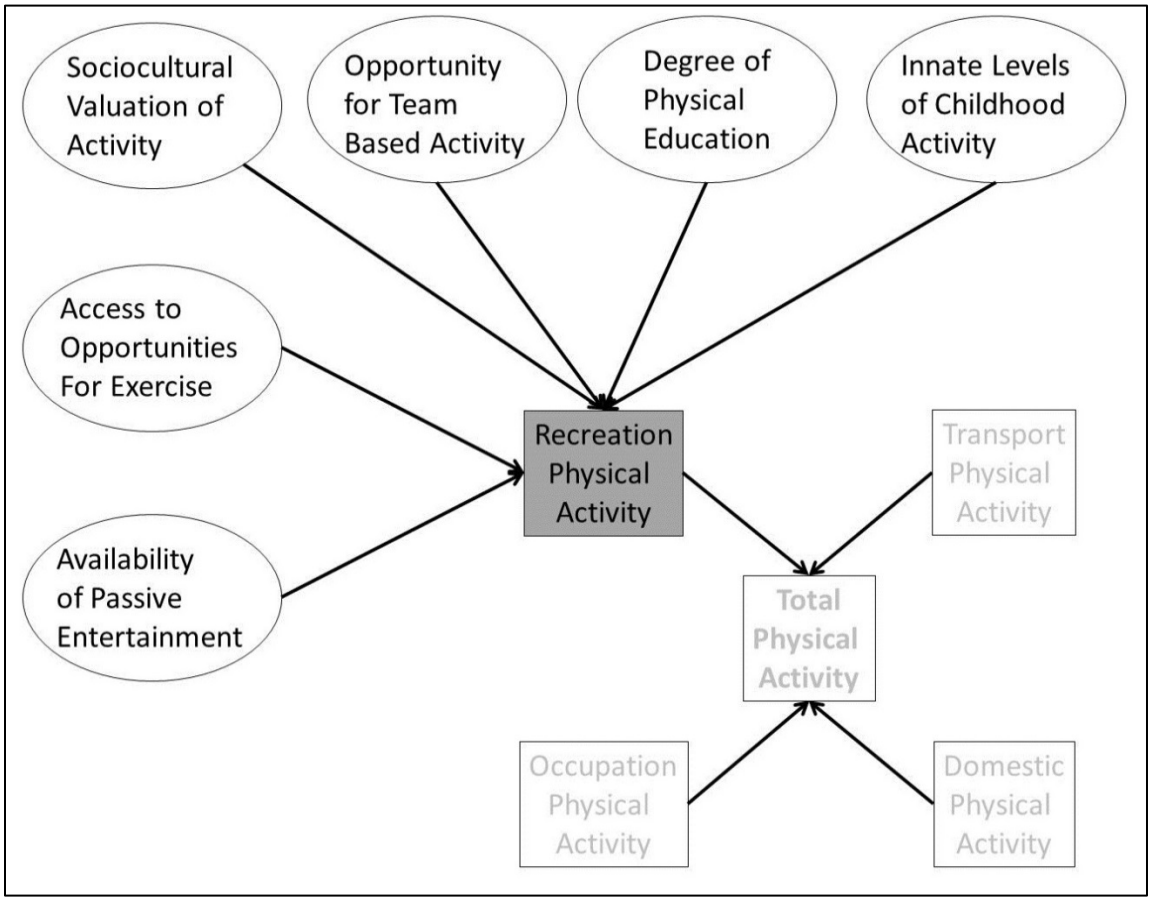

Figure 17: Theoretical model of the determinants of recreation physical activity behavior

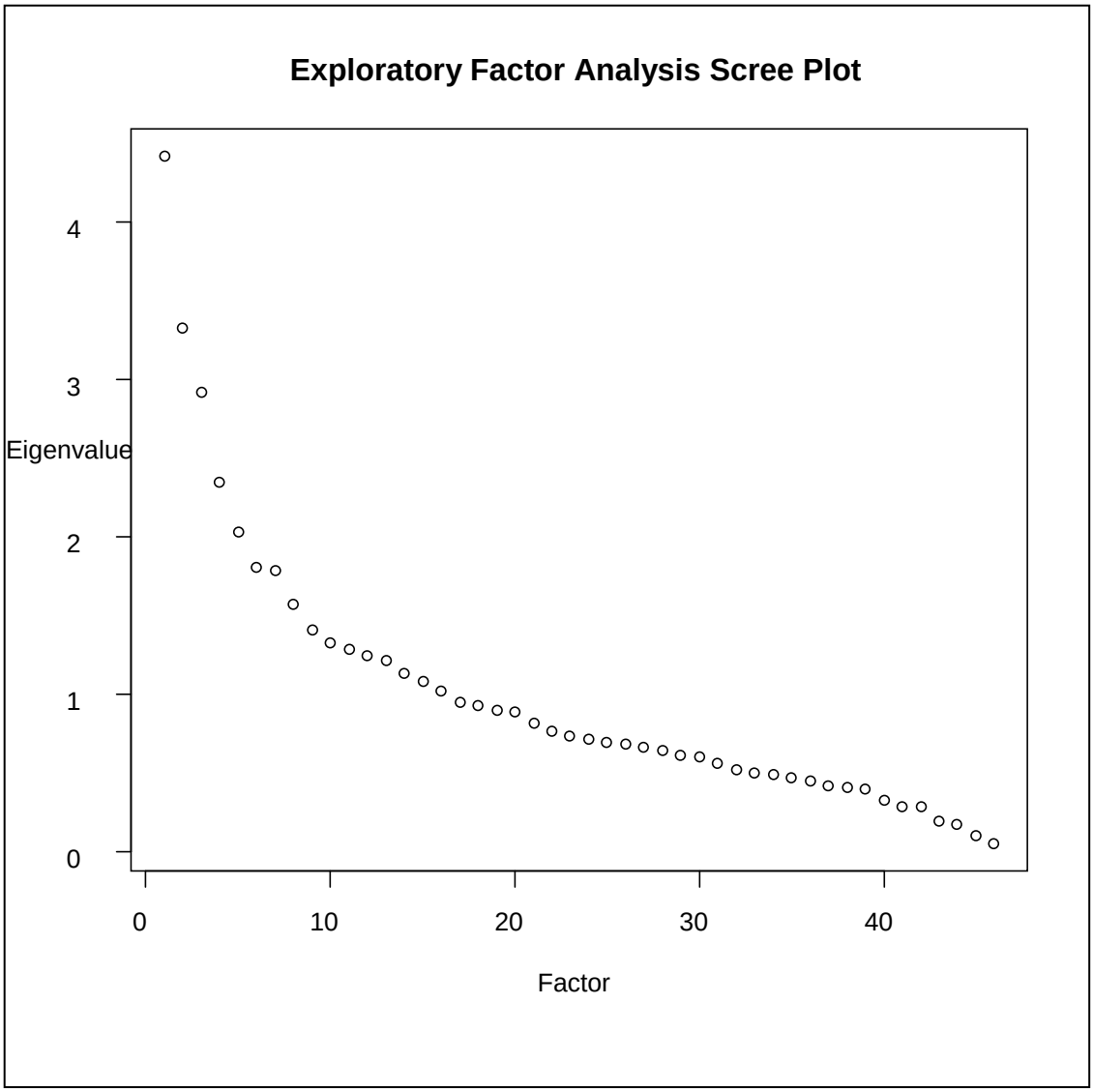

Figure 18: EFA Screeplot

Chapter 6. Manuscript 3: Personal, Social and Neighborhood Determinants of Adolescent Physical Activity by Ethnicity/race and Sex

Manuscript Abstract

Differences in environmental, social and personal determinants of physical activity are rarely compared across gender-specific ethnic and racial groups. This study tested for differences in determinants of moderate to vigorous physical activity (MVPA) between ethnicities/races and sexes in a large, diverse sample of adolescents. Interactions of 47 potential determinants with ethnicity/race on MVPA were tested in linear hierarchical regression models in males and females. Few determinants showed a difference in their association with MVPA by ethnicity/race in either sex. Among females, the determinants that differed by ethnicity/race were neighborhood road connectivity, perceived mother's physical activity and distance to the nearest trail. Among males, the determinants that differed by ethnicity/race were home media equipment and sports participation. Many determinants of MVPA are consistent across ethnicities/races, however, interventions to increase MVPA should take into account that some important determinants differ by ethnicities/races.

Introduction

Physical activity is a modifiable health behavior that has been shown to be protective against many chronic diseases including heart disease and cancer.[2] Objective measurements have shown that adolescence is a critical window during which physical activity behavior declines[1]. This decline occurs earlier among girls than among boys,[1] and reviews show that non-white adolescents report less MVPA than white adolescents.[10,11,16] The differences in MVPA between the sexes and between ethnicities/races invite the question of whether *determinants* of MVPA also differ by sex and ethnicity/race. Family support and self-efficacy have consistently been correlated with moderate to vigorous physical activity (MVPA) behavior[11,12]. However, aside from family support and self-efficacy, most modifiable determinants of MVPA remain poorly understood – possibly because the effects of some determinants on MVPA differ between groups within a population.

While many studies have examined potential determinants of physical activity behavior, relatively few have examined these in unique population subgroups, such as by ethnicity/race. We identified only 13 cross sectional[171,104,130,183,117,121,177,72,233,159,156,146,148] and two longitudinal studies[207,209] that examined differences in determinants of physical activity behavior between both sexes and between multiple ethnicities/races from the same sample. Examining differences within the same sample allows for greater control of other contextual factors, for example climate, that may also affect MVPA behavior and make comparisons of samples from different parts of the country difficult. More studies that undertake stratified analyses are therefore needed to better understand how the determinants of

MVPA behavior differ between groups within the same population. Previous analyses of the baseline data from the Project EAT-2010 cohort by Graham et al has identified determinants of MVPA in *the whole sample*.[212] This study aims to examine whether cross-sectional personal, social and neighborhood determinants of MVPA differ between groups defined by ethnicity/race and sex in this cohort.

Methods

Sample and Data Sources

Data for this analysis came from 2779 adolescents participating in the Project EAT-2010 (Eating and Activity in Teens) study and from their parents' responses to the Project F-EAT (Families and Eating and Activity among Teens) study. Project EAT-2010 is the first wave (baseline) of surveys from the 2009-2010 cohort of the Project EAT Study, which also includes a cohort that was assembled in 1999-1998 (EAT-I through EAT-IV) in the same schools. These coordinated surveys aimed to assess diet, physical activity, weight status, weight control behaviors and other associated factors in adolescents. These studies were approved by the University of Minnesota's Institutional Review Board Human Subjects Committee and by the participating school districts.

For EAT-2010, surveys and anthropometric measures were completed by adolescents from 20 public middle schools and high schools in the Minneapolis/St. Paul metropolitan area of Minnesota during the 2009-2010 academic year. The mean age of the study population was 14.4 years (SD=2.0) and adolescents were equally divided by sex (46.9% males, 53.1% females; Table 14). Trained research staff measured adolescents' height and weight using standardized procedures and administered surveys during selected health, physical education, and science classes. Measurements were

completed in a private area and surveys were administered during two class periods that were typically 45-50 minutes. The EAT-2010 survey is a 235-item self-report instrument assessing a range of factors of potential relevance to weight status and weight-related behaviors among adolescents. The survey was developed from previous Project EAT surveys[234,235], pilot testing and expert review, and organized around a social ecological framework and Social Cognitive Theory.[236,237]

For Project F-EAT, data were collected by surveying up to two parents/caregivers (n=3,709) of the adolescents in EAT-2010 about their own eating and physical activity behaviors, food-specific parenting practices, the home food environment, the home physical activity environment, the emotional atmosphere at home and the home weight culture. Approximately 30% of EAT-2010 participants provided contact information for one parent/guardian and 70% provided information for two parents/guardians. In total, 85.3% of adolescent participants in EAT-2010 had at least one parent respond. Parent participants had a mean age of 42.3 years (SD=8.6). The majority of parent respondents were mothers or other female guardians (62.0%). Parent surveys were collected by mail and by phone interviews. To meet the needs of the diverse sample, both forms of the survey were available in English, Spanish, Hmong, and Somali, and the telephone interview was additionally offered in Oromo, Amharic, and Karen.

Physical activity environments were assessed at the 20 participating middle schools and high schools from surveys completed by a school administrator and a physical education specialist. School administrators reported on policies and practices of relevance to physical activity. Physical education specialists reported on the availability

of physical education facilities and equipment as well as policies and practices relevant to the promotion of physical activity. All school staff were instructed to respond in regards to the 2009-2010 academic year and encouraged to confer with others at their school if they were unsure of current policies or practices.

The neighborhood assessment addressed features of home and school neighborhoods that were hypothesized to be related to MVPA. GIS data sources included land-use data, transit route data from MetroGIS,[238] police reports, and commercial databases (accessed through Esri Business Analyst, 2010).[239] ArcGIS Version 9.3.1 (ESRI, Redlands, California, 2009) was used for geocoding each participant's home address. Street network distances and densities were calculated; street network refers to a route between a participant's home and a destination that can be reached by someone on foot along a street network. Densities were calculated by dividing the total number of destinations by the land area, excluding water. Buffer distances of 800 m, 1600 m, and 3000 m were selected as prior research that has found that adolescents perceive an easy walking distance to be about 15 minutes and the average participant in this study was not of driving age.[240] Additional details on the protocol for neighborhood environment measures have been previously published.[230,241]

Analysis Variables

Variables were chosen for inclusion in this analysis based on their use in Graham et al's[212] previous study that examined non-stratified determinants of physical activity, or for their expected relevance as predictors of physical activity behavior. The determinants examined in this study were organized under a social ecological

framework,[3,5] and we have organized the determinants according to the social ecological constructs they were expected to reflect (Table 15).

Outcome: Moderate to Vigorous Physical Activity

Self-Reported Moderate and Vigorous Physical Activity (MVPA) was assessed using the Godin and Shepard questions.[213] These categories were converted to continuous hours using the values 0, 0.3, 1.3, 3.3, 5.3 and 8 respectively and the responses from moderate exercise and strenuous exercise were summed to get usual weekly hours of MVPA. In all models MVPA was treated as a continuous variable.

Expected Determinants:

Expected personal, social and neighborhood determinants were drawn from adolescent (EAT-2010) and parent surveys (F-EAT) as well as surveys of school administrators and physical education specialists and Geographic Information Systems measures derived from the home addresses that participants provided. These variables are grouped by the theoretical model construct they are expected to reflect and their distributional characteristics are described in Table 15.

Demographics:

Sex was self-reported by EAT-2010 participants as male or female. Ethnicity/Race was self-reported by EAT-2010 participants as one or more of: white, Black or African American, Hispanic or Latino, Asian American, Hawaiian or Pacific Islander, or American Indian or Native American. Participants who reported Hispanic or Latino ethnicity were classified as Hispanic or Latino regardless of racial identity. Non-Hispanic participants who reported two races with one race being "white" were classified as the non-white race they reported. Because of small sample sizes of

Hawaiian or Pacific Islander and American Indian or Native American, these groups were included in the mixed/other race category. Age in years was calculated by subtracting the participants' birthdates from the dates the survey was administered. Parent Education was self-reported by participants' parents with categories ranging from "Did not finish high school" to "Advanced degree". Parent Education was modeled as the maximum education attained by either of the participants' parents. Income was reported by the participants' primary parent by selecting among seven categories ranging from "Less than $20,000" to "$100,000 or more". Income was modeled as a continuous variable with a unit of $20,000 per year by assigning each category its median value and dividing by 20,000.

Missing Data

The range of missingness among the analyzed variables was 0% (most variables reported by teachers or school administrators) to 24.2% (average MVPA of participants' friends). To address the issue of missingness among some variables, all analyses were performed on a multiply-imputed dataset using SAS version 9.4 (2013, SAS Institute, Cary, NC, USA) Proc MI and Proc MIANALYZE. All predictors and covariates were used to create twenty imputed datasets using a MCMC algorithm. Multiple imputation methods for EAT-2010 analyses have been previously described in greater detail.[212]

Statistical Analysis

First, estimates of mean weekly hours of MVPA were calculated for each ethnicity/race within each sex. Next, tests for heterogeneity of associations (effect measure modification on the additive scale) with MVPA for each potential predictor variable by ethnicity/race were conducted within each stratum of sex. These tests were

conducted in linear mixed models adjusted for age, parent education and parent income with a random effect specified for school, to account for correlation in MVPA among students within the same school. All models used the multiply imputed dataset. As ethnicity/race is a categorical variable, the test-statistics are derived from the ANOVA type-3 f-statistic for the interaction term. To generate correct estimates of p-values from this statistic, the method of Raghunathan and Dong[231] to pool sum of square statistics in multiply imputed datasets was used. To account for the multiple tests run, we calculated the false discovery rate (FDR) for each test.[232] A lower value of FDR indicates lower probability that the discovery of a difference is in fact false. An FDR of 0.10, for example indicates that 1 in every 10 positive tests would be false-positives, or a 10% error in discovery. FDR was calculated from the table of raw p-values for the interactions of each predictor with ethnicity/race. Interaction terms with an FDR of 10% or less were considered strong evidence of an interaction. Interaction terms with an FDR of 10-20% were considered moderate evidence of an interaction.

Finally, variables that had strong or moderate evidence based on the FDR of heterogeneity in association with MVPA by ethnicity/race were examined in stratified hierarchical linear regression models. Models were stratified to 4 subgroups of ethnicity/race – white, African American, Hispanic and Asian – within each sex and adjusted for age, parent education and parent income. Models included a random effect for school. Post-hoc sensitivity analyses for these stratified models were conducted – adjusting for potential confounders beyond age, parent education and parent income, such as country of birth and neighborhood median income. Determinants in all stratified models were treated as continuous and linear in their association with MVPA except for

perceived mother's physical activity level among females, which was treated categorically due to a limited number of response options.

Additionally, a sensitivity analysis of the final stratified models using a windsorized MVPA variable as the outcome was conducted. The self-reported MVPA variable was windsorized – adjusted for possible over-reporting – based on a sub-study of 134 EAT-2010 students were measured for MVPA using accelerometers (unpublished analyses). Due to the cross-sectional and observational nature of this dataset, these coefficients should not be interpreted as causal effects.

Results

Levels of Physical Activity by Ethnicity/Race and Sex

Mean age adjusted levels of reported hours per week of MVPA showed significant difference by ethnicity/race within each sex (Table 16). Males reported higher levels of physical activity than females. Within each sex, non-white students reported lower levels of physical activity than white students (Table 16).

Tests for Association Heterogeneity

Among females, one variable - neighborhood road connectivity - showed strong evidence of differing by ethnicity/race in its association with MVPA (interaction term raw p-value = 0.0004, FDR = 0.04). Two variables among female showed moderate evidence of differing by ethnicity/race in their association with MVPA - perceived mother's level of physical activity (interaction term raw p-value = 0.004, FDR = 0.13) and distance to the nearest trail (interaction term raw p-value = 0.01, FDR = 0.19).

Among males, two variables showed moderate evidence of differing by ethnicity/race in their association with MVPA - count of home media equipment

(interaction term raw p-value = 0.004, FDR = 0.13) and sports participation (interaction term raw p-value = 0.009, FDR = 0.19)

Stratified Models

Neighborhood Road Connectivity among Females

Neighborhood road connectivity is the count of the number of local roads that intersect the perimeter of a 1600 meter buffer around the participant's house. This is an indicator of the walkability of the neighborhood, but also of the street network density. Among white and African American females, neighborhood road connectivity was not associated with weekly hours of MVPA. Among Hispanic and Asian females, every 10 point increment of neighborhood road connectivity (10 roads crossing the 1600 meter buffer around the participant's house) was associated with, respectively, 0.66 and 0.33 *fewer* hours per week of MVPA (Figure 19). These association estimates did not change substantially when models were adjusted for participant's country of birth or for the proportion of the participant's Census Tract in poverty.

Perceived Mother's Physical Activity among Females

Among non-white females, weekly hours of MVPA were higher at higher perceived levels of mothers' physical activity. These differences were statistically significant among African American and Hispanic females. White females who reported that their mothers sometimes or rarely were active reported significantly *fewer* hours per week of MVPA than females who reported their mothers were never active (Table 17).

Distance to Trails among Females

Although the association of distance in kilometers to the nearest trail with MVPA did not achieve statistical significance at $p < 0.05$ in any of the strata of ethnicity/race among females, the association estimates did show moderate evidence of heterogeneity by race. Among white and African American females, each kilometer closer to the nearest trail they lived was associated with 0.6 and with 0.4 more hours per week of MVPA respectively. Among Asian females, however, each kilometer closer to the nearest trail they lived was associated with 1.2 *fewer* hours per week of MVPA (Figure 20). These association estimates did not change substantially when models were adjusted participant's country of birth or for the proportion of the participant's Census Tract in poverty.

Home Media Equipment among Males

The availability of home media equipment was not associated with weekly hours of MVPA among African America and Asian males. By contrast, each additional home media device was associated with 0.24 fewer hours per week MVPA among white males. This association was reversed among Hispanic males with each additional home media device associated with 0.26 *more* hours per week MVPA (Figure 21). These association estimates did not change substantially when models were adjusted for nativity. Graham et al's[212] previous analysis did not include home media equipment, so we also conducted an unstratified analysis of this variable on MVPA to estimate a main-effects association. The unstratified association for home media equipment on MVPA was small ($\beta = 0.04$, 95% CI: -0.04 to 0.13) and not statistically significant.

Sports Participation among Males

Sports participation was associated with significantly more hours per week of MVPA among white, African American and Hispanic males. Among Asian males, the association estimate for sports participation with MVPA was far smaller than among the other ethnicities/races and did not achieve statistical significance (Figure 22).

Sensitivity Analysis using the Windsorized MVPA variable

Each of the stratified models was run using the windsorized MVPA variable as the outcome. The statistical significance and directions of associations did not differ between models using windsorized MVPA compared to models using non-windsorized MVPA. Regression coefficients from analyses using the windsorized MVPA outcome were about 1.5 times smaller than the coefficients using non-windsorized MVPA.

Discussion

This study found that hours per week of MVPA and some determinants of MVPA differ by ethnicity/race among adolescent males and females. White adolescent males and females reported significantly more time in MVPA each week than non-white males and females. Hispanic and Asian females showed an unexpected negative association of neighborhood road connectivity with MVPA. White females showed an unexpected negative association between their perceptions of their mothers' physical activity and their own MVPA. Asian females also showed unexpectedly more MVPA when living *further away from* trails. The availability of home media equipment had opposite associations among white and Hispanic males: correlating with less MVPA among white males and more MVPA among Hispanic males. Sports participation was positively associated with MVPA among boys, but this association was much weaker

and not statistically significant among Asian boys. Many of the differences by ethnicity/race are unexpected and future work will be necessary to clarify these somewhat confusing results. However, these results are part of a progression of further clarifying previous confusing results from main effects analyses of determinants of MVPA.[212]

This study built on a previous *main effects* analyses by Graham et al[212] that identified determinants of MVPA in the Project EAT participants stratified only on sex. Briefly, Graham et al[212] found that the personal determinants - self-efficacy, self-management, barriers, enjoyment and sports participation – explain 22% of the variation in MVPA in Eat-2010 participants, and that determinants at the family, school and neighborhood level explain less of the variation in MVPA. Encouragingly, we found that of 47 potential determinants of MVPA, only 5 showed heterogeneous associations with MVPA by ethnicity/race and sex. The general lack of heterogeneity among the associations will be useful to teachers and health practitioners planning physical activity interventions because it provides evidence that many aspects of the interventions do not need to be overly tailored. However, our study did find a few important differences in determinants of MVPA by ethnicity/race and sex that need to be further investigated and considered when planning interventions.

Neighborhood Road Connectivity

The finding that neighborhood road connectivity, which is expected to be an indicator of neighborhood walkability, is negatively associated with MVPA in Asian and Hispanic females was unexpected. As the Asian participants in Project EAT-2010 were primarily Hmong ethnicity, a recent immigrant group that began arriving in America in

the 1970s, we hypothesized that acculturation or neighborhood poverty may be confounding this association. However, a post hoc adjustment for the participant's country of birth and for neighborhood proportion living in poverty did not change the associations.

A previous review[19] showed that neighborhood road connectivity had no association with MVPA in 19 studies and a positive association in 5 studies. Graham et al[212] found a negative but not statistically significant main effect of neighborhood road connectivity on MVPA in EAT-2010 participants. In a sample of predominantly white adolescents in the Twin Cities, Patnode et al[144] found a *positive* association of walkability – a measure that includes street connectivity – with MVPA among females but not among males. However, unlike Patnode et al[144], our study considered road network in isolation from presence of destinations. Presumably *both* would be needed to increase MVPA. It may be that immigrant groups live in neighborhoods with a high road density but low density of destinations, which could explain our finding of a negative association of MVPA with neighborhood road connectivity in Asian and Hispanic females. Future work should be undertaken to better understand this finding.

Mother's PA

A previous review[12] found that parental activity was generally uncorrelated with adolescent physical activity. Graham et al[212] found a positive and statistically significant main-effect of perceived mother's physical activity on MVPA among female EAT-2010 participants in unadjusted models, but this association turned negative and was no longer statistically significant in a model adjusted for all determinants at once. While we found a negative association between perceived mother physical activity and

MVPA among white females, among non-white females there was a positive association with perceived mothers' physical activity. The negative association in white females was an unexpected finding and should be interpreted with caution, particularly given that self-report of MVPA and of perceived mother's physical activity both may be subject to social desirability bias. We were only able to identify four studies[69,166,203,191] that examined the association of perceived mother physical activity with females' physical activity in unique subgroups by ethnicity/race. Therefore, it remains possible that reviews of the associations of mothers' physical activity with daughters' physical activity were inconclusive because the association differs within population subgroups that have not been adequately studied.

Distance to Trails

Our results help to further clarify one of Graham et al's[212] more unexpected findings – that greater distance to the nearest trail predicted more MVPA. We would expect that more MVPA would be related to living *nearer* to a trail. Our results show that white and African American females show the association in the expected direction, though these associations are not statistically significant. The association in the unexpected direction is among Asian females. Previous qualitative work has shown that Hmong immigrants to the United States feel out of balance with the environment and not able to be physically active as they were in Laos – farming in fields.[242,243] Taken together with the finding of more physical activity with lower neighborhood road connectivity, this may suggest that a less dense urban form is more conducive to physical activity among the Hmong. This may be especially pronounced among Hmong females, as quantitative work also shows that parental concerns for safety are higher for

female children.[242] Further study will be needed to determine if interventions in neighborhoods of denser form can increase MVPA in Hmong females, and future studies of determinants should examine the impact of access to specific neighborhood destinations. For example, if physical activity among the Hmong was – in Laos – primarily agricultural, does living in a neighborhood with a community garden correlate with greater MVPA?

Home Media Equipment

Home media equipment availability is a potentially modifiable determinant of sedentary behavior, which in turn may be correlated with MVPA. The associations of sedentary behavior and home media equipment with physical activity are rarely tested for differences by ethnicity/race and sex. We identified only three studies[130,117,121] that measure the association of sedentary behavior with physical activity in subgroups of ethnicity/race and sex. We are aware of two studies that considered the association of home media equipment – having cable TV or internet access – with physical activity.[123,68] McMinn et al found that internet access was associated with lower physical activity, and the association did not differ by ethnicity/race among British school children.[123] Baskin et al[68] found, as we did, that media availability was not associated with physical activity among African American children. However, Baskin restricted their sample so comparisons across ethnicities/races were not possible. As far as we are aware, the present study is the first to show that there may be differences in the association of media equipment availability with MVPA by ethnicity/race and sex. Further studies will be needed to examine the potential mechanisms behind the finding that greater media equipment availability predicts less MVPA in white adolescents and

predicts more MVPA in Hispanic adolescents. Specifically, it will be important to determine if home media equipment mediates a relationship between sedentary behavior and MVPA and if there are any other moderators or confounders that can further explain this difference.

Sports Participation

We found that sports participation is not as strong a determinant of MVPA among Asian males as it is among males of other ethnicities/races. This is an important finding as Graham et al[212] found sports participation to be one of the strongest *main effects* determinants of MVPA in the EAT-2010 sample, and previous reviews[11] have shown that participation in community sports is positively related to physical activity. Our findings suggest that Asian males in EAT-2010, primarily Hmong ethnicity, are getting less of their MVPA through sports participation. This finding has many possible implications for interventions: first, that interventions to increase MVPA in Asian American males, and particularly Hmong, should focus on non-sport activity; and further, that the sport offerings in the community should be expanded to match the preferences of the Asian American males. Future work will be needed to clarify how best to design physical activity interventions for this population.

Strengths and Limitations

The major strength of this study is its diversity of both participants and of variables. With over 200 participants in each of eight groups of ethnicity/race and sex, we were able to examine differences in physical activity behavior and its determinants by ethnicity/race and sex in ways that are rarely possible. And, while drawing all participants from one metropolitan area may limit generalizability to some extent, it also

ensures that potential confounders like climate are balanced across the subgroups. This strengthens our comparisons across the ethnicities/races.

A further strength of this study was that it combined measures of multiple potential determinants of MVPA behavior at the environmental, social and personal level to allow a clearer picture of differences in determinants at multiple levels of the social-ecological framework. The multiple predictors included both objective measures and measures of perception at each level. Our study, having both objective and perception measures, allowed an examination of which may be more important in differentially predicting MVPA by ethnicity/race and sex.

A limitation of this study is the possibility of reverse causality. Data for this study came from the baseline measurement of an ongoing longitudinal cohort study. Therefore, all analyses were cross-sectional and the temporality of the association between the determinants and MVPA cannot be established. Future studies will need to be conducted to test these associations longitudinally.

Another limitation of this study is the possibility of measurement error in the measure of MVPA. MVPA in this study was self-reported. Self-report measures of MVPA may capture some modes of physical activity like biking, swimming or contact sports that are commonly missed by accelerometer measures. However, self-report measures are also more subject to social desirability bias than accelerometry. We conducted a sensitivity analysis that showed that the statistical significance and direction of the association estimates did not differ between models using the windsorized MVPA compared to models using non-windsorized MVPA.

Conclusions

Physical activity behavior and its determinants are not likely to be completely homogenous within any population. While many determinants of MVPA in this study did not show evidence of differing by ethnicity/race in this study, a few important determinants did differ by ethnicity/race. Failing to consider how determinants differ among populations and among groups within populations may be one reason that the modifiable determinants of MVPA remain poorly understood. Sports participation and perceived mother's physical activity may be more important determinants of MVPA in some ethnic/racial groups than in others. Modifiable environmental determinants including home media availability and neighborhood road connectivity and distance to trails had different associations with MVPA within strata defined by ethnicity/race and sex. Future studies should be conducted to better understand mechanisms of these differences. Particularly, determining why sports participation may have different associations with MVPA when comparing Asian males to white, Hispanic and African American males will be important. Understanding different associations of urban form with MVPA will also be important, especially determining the importance of having both destinations and a connected road network in a neighborhood to increasing MVPA, and considering how the density of the urban form may have different associations with MVPA for different groups within the population. Future interventions to increase MVPA should account for potential differences in their effect within different groups.

Tables

Table 14: Sample Descriptives for EAT-2010	
Total Sample	2779 (100%)
Age: Mean (SD)	14.4 (2.0)
MVPA: Mean (SD)	5.8 (4.7)
Demographics	
Ethnicity/Race and Sex	
Male	1302 (46.9%)
White	277 (10.0%)
African American	378 (13.6%)
Hispanic	252 (9.1%)
Asian	260 (9.4%)
Mixed or Other	135 (4.9%)
Female	1477 (53.1%)
White	248 (8.9%)
African American	428 (15.4%)
Hispanic	311 (11.2%)
Asian	293 (10.5%)
Mixed or Other	197 (7.1%)
Parent Education	
Less than High School	616 (23.4%)
High School	556 (21.1%)
Some College	748 (28.4%)
Bachelor's Degree	476 (18.1%)
Advanced Degree	239 (9.1%)
Parent Income	
Less than $20,000	846 (37.6%)
$20,000 – $34,999	516 (22.9%)
$35,000 – $49,999	351 (15.6%)
$50,000 – $74,999	266 (11.8%)
$75,000 – $99,999	137 (6.1%)
$100,000 or more	137 (6.1%)

Table 15: Possible Determinants of MVPA by Expected Project-Foresight Construct

Variable (Unit)	*Source*	*Mean (SD)*	*Description*
Inclination to Activity			
Physical Activity Enjoyment (Range: 3-12)	Adolescent Report (EAT-2010)	5.26 (2.25)	3 item scale (Cronbach's alpha = 0.82)
Physical Activity Barriers (Range: 4-20)	Adolescent Report (EAT-2010)	9.73 (3.22)	4 item scale (Cronbach's alpha = 0.49)
Physical Activity Self-Efficacy (Range: 3-12)	Adolescent Report (EAT-2010)	7.86 (2.38)	3 item scale (Cronbach's alpha = 0.76)
Physical Activity Self-Management (Range: 5-15)	Adolescent Report (EAT-2010)	8.82 (3.14)	3 item scale (Cronbach's alpha = 0.82)
BMI (z-score)	Measured by Research Staff	0.71 (1.07)	Z-score of BMI measured as kg/m^2
Past Year Substance Use (yes/no)	Adolescent Report (EAT-2010)	3.85 (1.88)	Participant Used Alcohol, Cigarettes or Marijuana in the past year (test-retest reliability: r = 0.83)
Depression (Range: 6-18)	Adolescent Report (EAT-2010)	10.21 (3.01)	6 item scale (Cronbach's alpha = 0.83)
Opportunities for Team Based Activity			
Activity Fee (Range: 1-3)	PE Specialist Survey	2.23 (0.52)	Students must pay an activity fee to participate in any sport, intramural or physical activity clubs? (No/Waiver Available/Yes)
Availability of a Sport Bus (yes/no)	PE Specialist Survey	61% Yes	School has an afterschool bus for sports, academic, club, or discipline reasons (yes/no)
Distance to the Nearest Gym (km)	GIS	1.26 (0.73)	Distance (km) to nearest gym
Distance to the nearest Rec Center (km)	GIS	0.52 (0.37)	Distance (km) to nearest Rec Center
Participation on Sports Teams (count)	Adolescent Report (EAT-2010)	2.03 (1.06)	"During the past 12 months, on how many sports teams did you play?" (test-retest reliability: r = 0.86)
Opportunities for Exercise			
Density of Parks near Home (percent)	GIS	9.5 (7.4)	Percent of 1600m Buffer around home that is Greenspace
Indoor Physical Education Facilities at School (count)	PE Specialist Survey	4.55 (1.96)	Count of Indoor Activity facilities reported by PE Specialist
Outdoor Physical Education Facilities at	PE Specialist Survey	3.74 (1.36)	Count of Outdoor Activity facilities reported by PE Specialist

Table 15: Possible Determinants of MVPA by Expected Project-Foresight Construct

Variable (Unit)	*Source*	*Mean (SD)*	*Description*
School (count)			
Perceived Neighborhood daytime safety (unsafe_day_10)	Adolescent Report (EAT-2010)	1.72 (0.9)	"The crime rate in my neighborhood makes it unsafe to go on walks during the day." (test-retest reliability: r = 0.57)
Perceived Neighborhood nighttime safety (unsafe_night_10)	Adolescent Report (EAT-2010)	2.29 (1.14)	"The crime rate in my neighborhood makes it unsafe to go on walks during at night." (test-retest reliability: r = 0.65)
Busy Streets in Neighborhood (count)	GIS	1.96 (0.95)	Percent of streets in 1600m Buffer around home that are busy
Distance to the nearest Trail (kilometers)	GIS	0.64 (0.47)	Street network distance (km) to nearest bike or walking trail
Neighborhood Road Connectivity (10 count of Access Points)	GIS	6.62 (1.67)	Count of streets crossing into 1600m buffer around home (unit= 10 crossings)
Reported Neighborhood Crime (count)	GIS	1.72 (0.97)	Count of total crimes per hectare near home in 2010
Distance to School (kilometers)	GIS	5.92 (4.58)	Street network distance (km) to school
Home Physical Activity Equipment (Range 0:5)	Parent Report (F-EAT)	2.28 (1.37)	Parent reported count of exercise equipment available at home. (test-retest reliability: percent concordance = 80% to 89%)
Social Norms			
Perceived Mother's PA (mom_pa_10)	Adolescent Report (EAT-2010)	2.48 (0.99)	"My mother is physically active in her free time." (test-retest reliability: r= 0.70)
Perceived Father's PA (dad_pa_10)	Adolescent Report (EAT-2010)	2.54 (1.08)	"My father is physically active in his free time." (test-retest reliability: r= 0.69)
Parent Self-Reported PA (hours/week)	Parent Report (F-EAT)	4.08 (3.7)	Parent reported moderate and vigorous physical activity (Godin-Shepard, test-retest reliability: r = 0.56 to 0.75)
Parent Active with Child (hours/week)	Parent Report (F-EAT)	1.22 (1.53)	Hours per week parent is active with their adolescent (test-retest reliability: r = 0.58)
Family does Active Things (Range: 1-4)	Adolescent Report (EAT-2010)	2.59 (0.98)	"My family and I do active things together." (test-retest reliability: r = 0.73)
Family Support for Physical Activity (Range: 1-4)	Adolescent Report (EAT-2010)	3.14 (0.92)	"My family supports me in being physically active." (test-retest reliability: r = 0.60)
Parent helps Child be Active (hours/week)	Parent Report (F-EAT)	1.52 (1.86)	Hours per week parent helps their adolescent be physically active (test-retest reliability: r = 0.62)
Parent Talks to Child about being	Parent Report (F-	2.97 (1.2)	"Have you had a conversation with your child about being physically

Table 15: Possible Determinants of MVPA by Expected Project-Foresight Construct

Variable (Unit)	*Source*	*Mean (SD)*	*Description*
Active (Range: 1-5)	EAT)		active?" (test-retest reliability: r = 0.64)
Friends Play Sports (Range: 1-4)	Adolescent Report (EAT-2010)	3.18 (0.81)	"My friends often play sports or do something active." (test-retest reliability: r = 0.54)
Friends think it is Important to be Active (Range: 1-4)	Adolescent Report (EAT-2010)	2.91 (0.83)	"My friends think it is important to be physically active." (test-retest reliability: r = 0.43)
Friends are Active Together (Range: 1-4)	Adolescent Report (EAT-2010)	3.1 (0.87)	"My friends and I like to do active things together." (test-retest reliability: r= 0.49)
Friend Self-Reported Physical Activity (hours/week)	Adolescent Report (EAT-2010)	6.19 (3.61)	Mean of Godin Shepard self-reported MVPA among nominated friends.
School Physical Activity Promotion (Range: 1-5)	School Administrator Survey	3.49 (0.77)	"To what extent has your school made a serious effort to promote increased physical activity among students?"
Average Physical Activity of Students in School (hours/week)	Adolescent Report (EAT-2010)	5.78 (0.72)	Mean of Godin Shepard self-reported MVPA among students within the school.
Degree of PE			
10 Year change in PE budget (yes/no)	PE Specialist Survey	0.37 (0.48)	"Over the past 10 years, has there been a change in the budget for physical education equipment and supplies at this school?"
Time spent in PE in an average week (hours/week)	PE Specialist Survey	3.91 (1.5)	"On average, how many minutes per week do students at your school participate in physical education?"
School's Required Physical Education Credits (credits/year)	PE Specialist Survey	0.65 (0.58)	"What is the minimum physical education requirement for students at your school?"
Had gym class in the last year (yes/no)	Adolescent Report (EAT-2010)	47% Yes	Adolescent participated in gym class in the past year.
Passive Entertainment			
Video Games in Bedroom (yes/no)	Adolescent Report (EAT-2010)	64% Yes	In the room where you sleep, do you have an electronic games console?" (test-retest reliability: percent concordance = 94%)
TV in Bedroom (yes/no)	Adolescent Report (EAT-2010)	39% Yes	In the room where you sleep, do you have a television?" (test-retest reliability: percent concordance = 97%)
Screen Time (hours/day)	Adolescent Report (EAT-2010)	5.74 (3.82)	Hours per day watching TV, using a computer, or playing video-games. (test-retest reliability: r = 0.86)
Parent watches TV with Child (hours/week)	Parent Report (F-EAT)	2.38 (1.92)	Hours per week parent watches TV with their adolescent (test-retest reliability: r = 0.53)

Table 15: Possible Determinants of MVPA by Expected Project-Foresight Construct			
Variable (Unit)	***Source***	***Mean (SD)***	***Description***
Parent TV hours (hours/week)	Parent Report (F-EAT)	14.35 (9.14)	"On an average day, how many hours do you spend watching TV, DVD's, or videos?" (test-retest reliability: r = 0.78)
Home Media Equipment (count)	Parent Report (F-EAT)	7.75 (3.33)	Parent reported count of exercise media equipment available at home. (test-retest reliability: r = 0.73 to 0.90)

Table 16: Age Adjusted Mean Weekly Hours of Self-Reported Moderate to Vigorous Physical Activity by Ethnicity/race and Sex in EAT-2010

	Mean MVPA [95% CI]
Female	5.0 [4.8 to 5.2]
White	6.3 [5.7 to 6.8]
African American	4.9 [4.4 to 5.3][a]
Hispanic	4.3 [3.8 to 4.8][a]
Asian	4.4 [3.9 to 4.9][a]
Male	6.7 [6.4 to 6.9]
White	7.9 [7.3 to 8.4]
African American	6.8 [6.3 to 7.2][b]
Hispanic	6 [5.4 to 6.6][b]
Asian	5.8 [5.2 to 6.4][b]

[a]Significantly different from White Females at Bonferroni-corrected $p < 0.05$
[b]Significantly different from White Males at Bonferroni-corrected $p < 0.05$

Table 17: Ethnicity/race stratified estimates for associations of Perceived Mother's PA with MVPA (hours per week) among Females in EAT-2010[a]

	White Females	*African American Females*	*Hispanic Females*	*Asian Females*
Perceived Mother's Physical Activity				
Regular	-1.25 [-3.15 to 0.64]	2.21 [0.88 to 3.55][b]	2.38 [1.02 to 3.75][b]	0.55 [-1.15 to 2.24]
Sometimes	-2.04 [-3.78 to -0.30][b]	1.74 [0.59 to 2.88][b]	1.10 [-0.11 to 2.31]	1.01 [-0.35 to 2.37]
Rarely	-1.77 [-3.47 to 0.07][b]	0.13 [-1.06 to 1.31]	1.01 [-0.16 to 2.18]	1.17 [-0.18 to 2.51]
Never	0 [Ref]	0 [Ref]	0 [Ref]	0 [Ref]

[a]Model adjusted for age, parent education and parent income

[b]Significantly different from the reference level at $p < 0.05$

Figures

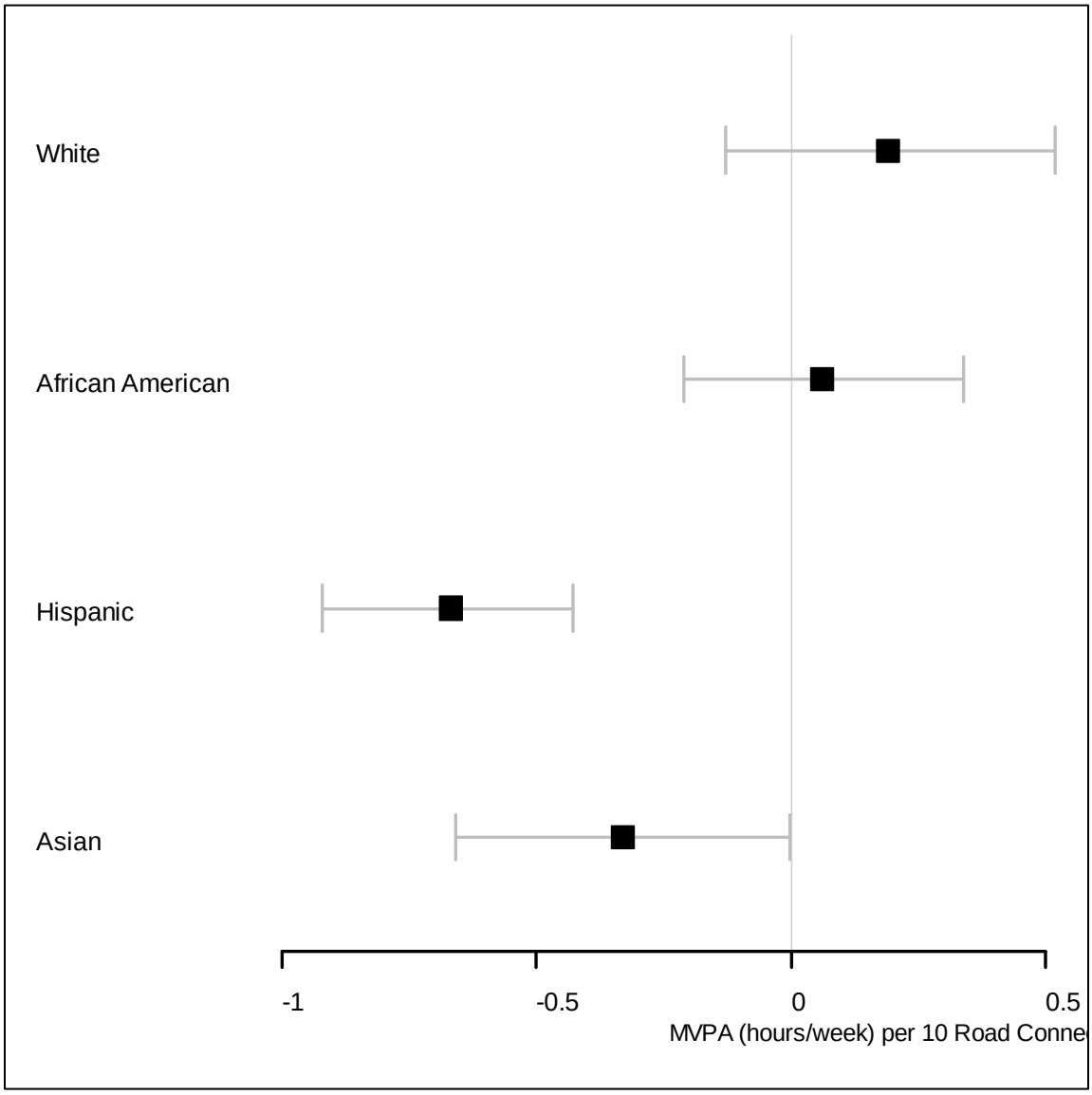

Figure 19: Association of Neighborhood Road Connectivity with MVPA by Race among Females in EAT-2010

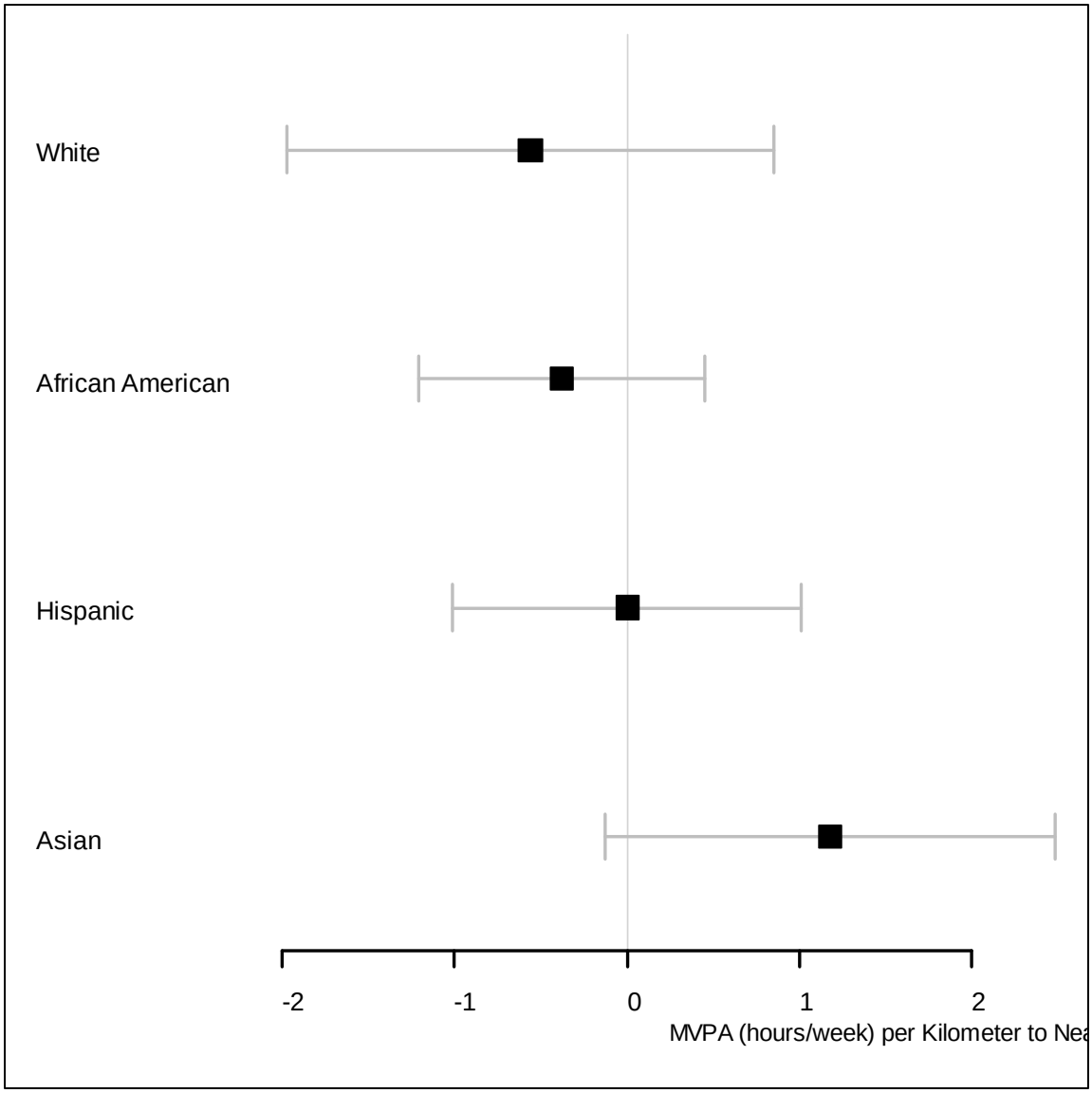

Figure 20: Association of Distance to Trail with MVPA by Race among Females in EAT-2010

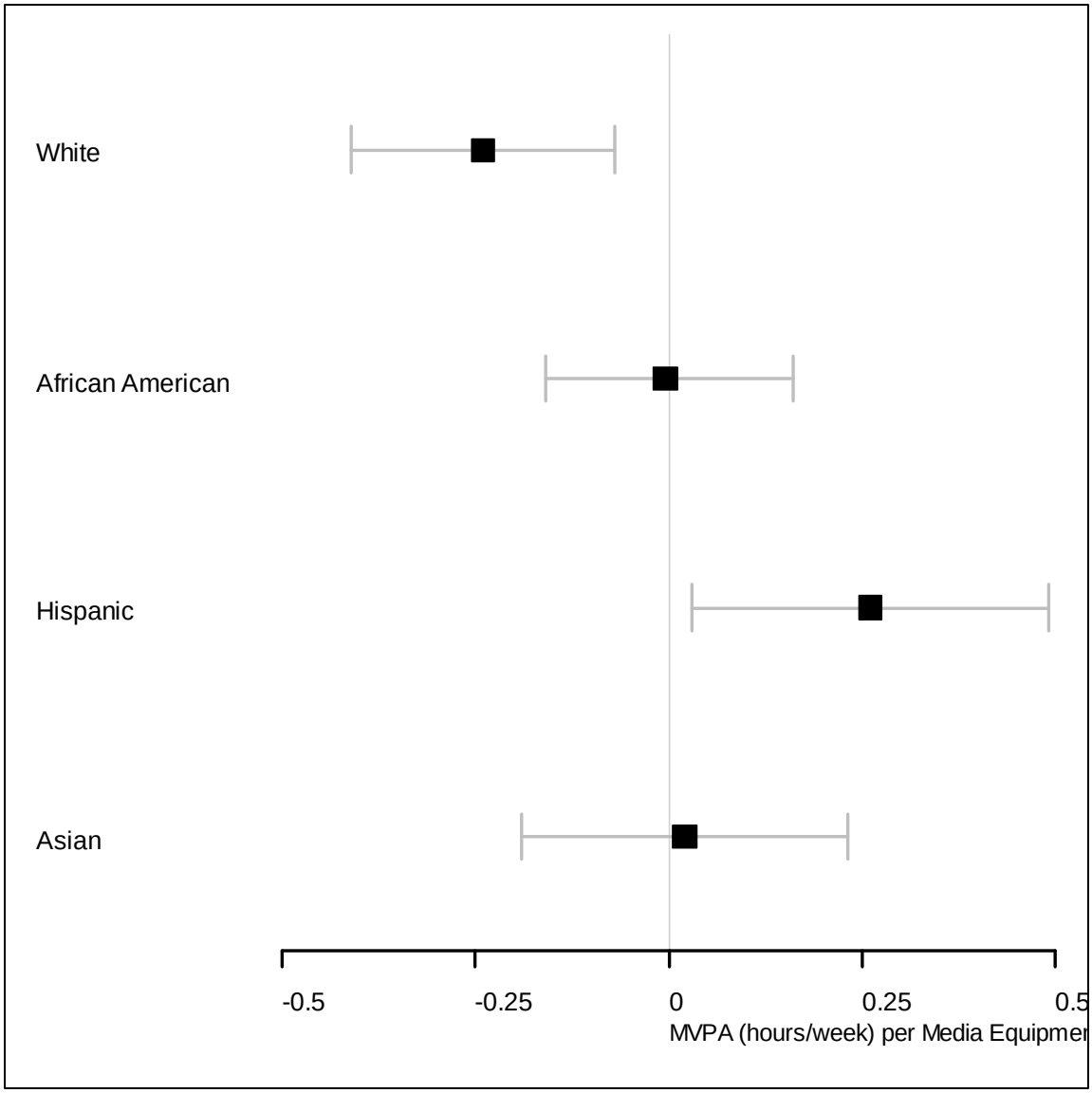

Figure 21: Association of Home Sedentary Equipment with MVPA by Race among Males in EAT-2010

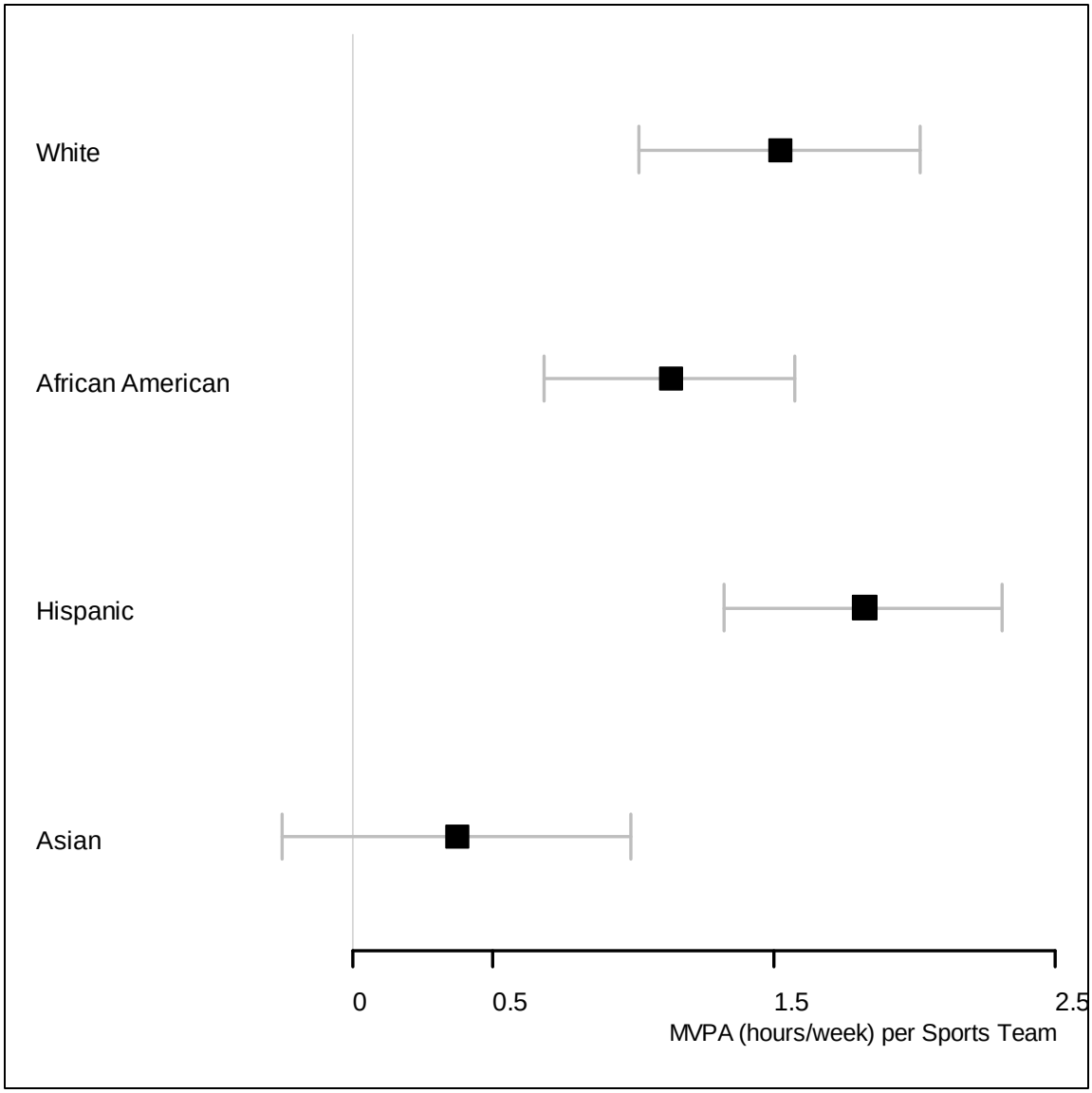

Figure 22: Association of Sport Participation with MVPA by Race among Males in EAT-2010

Chapter 7. Manuscript 4: Developmental Trends and Determinants of Physical Activity from Adolescence to Adulthood differ by Race and Gender

Manuscript Abstract

Background: Regular physical activity protects against many chronic diseases. Yet, interventions to raise population physical activity generally show modest effects; one possible reason is that trends and determinants of moderate to vigorous physical activity (MVPA) differ between population subgroups. This study examined differences in trends in and determinants of reported MVPA by ethnicity/race and sex in a 15 year longitudinal study.

Methods: 2902 participants in the Project EAT study were surveyed on MVPA behavior and potential personal and social determinants at four waves of follow-up from adolescence to young adulthood. Generalized estimating equations were used to model age trends in MVPA and associations with determinants.

Results: Mean MVPA declined by 2.1 hours per week over 15 years of follow-up from adolescence to young adulthood. Trends in MVPA differed by sex and ethnicity/race. All groups of ethnicity/race by sex showed significant decreases in MVPA with age except for African American and Hispanic males. Among males, Asians reported the lowest levels of MVPA at each age. African American and Asian females reported less MVPA than white females at each age. The association of body mass index (BMI) with MVPA differed both by sex and ethnicity/race. Asian males and females showed lower levels of MVPA at both low and high BMI.

Conclusions: Interventions to increase MVPA may need to begin earlier among Asian men and African American and Asian women than among other groups. Asian youth

with lower BMI show lower MVPA, and may benefit from additional intervention efforts during adolescence.

Introduction

In much of the world, physical activity is declining as advances in technology and shifts to sedentary forms of employment reduce activity at work, home and for transportation. Lack of physical activity is linked to obesity, heart disease and cancer,[2] and is implicated in over three million preventable deaths per year globally.[215,244] Therefore, it is a high public health priority to promote life-long physical activity.

In the United States, 40% of children under 12 years of age achieve the recommended 60 minutes of moderate to vigorous physical activity (MVPA) per day.[1] This proportion is only 8% among adolescents and only 5% of adults meet the recommendation of 30 minutes per day of MVPA.[1] There is a clear need to intervene to increase population levels of MVPA in the United States. However, the modifiable determinants of MVPA are poorly understood, and determinants of MVPA may differ across groups within a population. Determinants of physical activity like screen-time and confidence in overcoming barriers differ by sex.[245] Barriers to MVPA, like low parent knowledge of physical activity recommendations or neighborhood design barriers, differ by ethnicity/race.[246,247] Yet, few studies have quantified the determinants of, or trends in MVPA, both across race/ethnicities and between the sexes at the same time.

To our knowledge, 13 longitudinal studies have examined determinants of physical activity in subgroups of both ethnicity/race and sex.[204,192–194,185,203,199,207,189,208,209,191,190] Of these 13 studies, only two studies examined determinants in stratified subgroups of both sexes and more than one ethnicity/race.[207,209]

Improved understanding of differences in determinants of MVPA and trends over time in population subgroups may be crucial for targeting appropriate interventions to increase life course MVPA. Therefore, the current analysis aimed to examine the following questions: 1. What are the trends of MVPA from adolescence to young-adulthood? 2. Do the trends of MVPA from adolescence to young adulthood differ by ethnicity/race and sex? 3. Do longitudinal determinants of MVPA differ between these groups?

Methods

Study Design

Project EAT (Eating and Activity in Teens and Young Adults) is a 15 year longitudinal study with four waves of follow-up and a large, diverse sample that allows examination of trends in and determinants of MVPA from adolescence to adulthood in subgroups of ethnicity/race and sex. The Project EAT surveys examined dietary intake, physical activity, weight-control behaviors, weight status, and associated factors among young people. Surveys at EAT-I (1998 - 1999) were completed during classes at 31 public junior and senior high schools in the Minneapolis-St. Paul metropolitan area of Minnesota.[235,248] At each wave of follow-up (EAT-II: 2003 - 2004, EAT-III: 2008 - 2009 or EAT-IV: 2015 - 2016) participants completed online or mailed paper surveys. All surveys can be accessed at http://www.sphresearch.umn.edu/epi/project-eat/#survey. The sample for this analysis was 2902 participants in the Project EAT-I survey who completed at least one of the three follow-up surveys. The analysis sample was relatively evenly split between the sexes and among levels of baseline SES (Table 1). All ethnicity/race by sex groups had sample sizes over 80, meaning that stratified models could reasonably be run (Table 1). The University of Minnesota's Institutional Review

Board approved all protocols for Project EAT at each time point. All participants gave informed consent at each time point.

Variables

Moderate to Vigorous Physical Activity (MVPA)

MVPA was assessed using questions modified from Godin and Shepard at each wave of follow-up.[213] The questions ask about hours per week spent in mild, moderate or strenuous exercise. Moderate and strenuous exercise were summed to obtain hours per week of MVPA. This self-report measure was validated with accelerometers in a sub-sample of 121 respondents at EAT-III.[249] Sirard et al found a correlation of 0.43 between the self-report and accelerometer measured MVPA at EAT-III, and that self-report did not systematically over or underestimate MVPA compared to accelerometer measurements.[249]

Ethnicity/race

Ethnicity/race was self-reported at EAT-I. Respondents chose one or more categories with which they identified from: White, Black or African American, Hispanic or Latino, Asian American, Hawaiian or Pacific Islander, or American Indian or Native American. Respondents who reported Hispanic or Latino ethnicity were classified as Hispanic or Latino regardless of racial identity. Non-Hispanic respondents who reported two races with one race being "white" were classified as the non-white race they reported. Because of small sample sizes of Hawaiian or Pacific Islander and American Indian or Native American, these groups were included in the mixed/other race category.

Sex

Sex was self-reported at EAT-I as male or female.

Socioeconomic Status

Socioeconomic Status (SES) was created from the maximum parent education attainment reported at EAT-I (baseline). Level of SES was adjusted down if the respondent was on public assistance, free or reduced lunch or neither parent was employed.[248] The five categories were ordered with the highest category representing highest SES and the lowest category representing lowest SES.

Age

Age in years at each follow-up was self-reported or calculated by subtracting the respondent's birthdate from the survey-completion date. To account for possible non-linearity in MVPA over the life course, age was categorized as: middle school (11 to 13 years), high school (13 to 18 years), college-age (18 to 22 years), young adult (22 to 30 years), 30+ (30 to 36 years). These categories were chosen to reflect ages where major life changes may change MVPA behavior.

Determinants

Eight variables – BMI, screen-time, sports participation, substance use, personal fitness concerns, depression, parent fitness concerns and friend fitness concerns – were selected as potential determinants of MVPA. These variables were chosen because they have previously been associated with physical activity behavior.[11]. All determinants except sports participation and parent fitness concerns (measured only at baseline) were lagged by five years. Reliabilities were assessed with two week retests in subsamples of the participants at EAT-I, EAT-III.[235,250]

BMI

Height and weight were measured by trained research staff at baseline (EAT-I) and used to calculate body mass index (BMI) in kg/m^2.[248] Height and weight were also self-reported at EAT-I and these values were used for respondents who did not have a measured BMI. The correlations between measured and self-reported heights and weights at baseline were high (females: 0.85, males: 0.89). BMI was calculated from respondents' self-reported height and weight at each wave of follow-up. The test-retest correlation at EAT-III was 0.99 for both height and weight.

Depression

Depression was measured at each wave of follow-up from responses to the Kandel and Davies depression scale.[251] This scale was categorized into high depressive symptoms (scores over 23), moderate depressive symptoms (scores between 18 and 22) and low depressive symptoms (scores 17 and below) as previously described.[251,252] Cronbach's alpha for these items was 0.82 at EAT-I and EAT-II and 0.83 at EAT-III.

Personal Fitness Concerns

Personal fitness concerns were measured at EAT-I, II and III from responses to the question, "How much do you care about staying fit and exercising?" There were four response options from "not at all" to "very much". The test-retest correlation was 0.51 at EAT-I and 0.75 at EAT-III.

Sports Participation

At baseline, sports participation was assessed using the question, "During the past 12 months, on how many sports teams did you play?" Sports participation was dichotomized to

compare respondents who participated on any teams to respondents who participated on no teams. The test-retest correlation was 0.84 at EAT-I

Screen-time

Participants were asked about daily hours of TV and video use and daily hours of computer use separately for weekdays and weekends. Total weekly hours of screen-time were calculated. The test-retest correlations ranged from 0.69 to 0.81 at EAT-I and from 0.74 to 0.90 at EAT-III.

Substance Use

Participants were asked about past-year cigarette, alcohol and marijuana use. Substance use was dichotomized to compare participants who never used any substance in the past year to participants who ever used any substance in the past year. The test-retest correlations ranged from 0.77 to 0.81 at EAT-I and from 0.91 to 0.94 at EAT-III.

Parent Fitness Concerns

At baseline, participants were asked how much their mother and father care about staying fit and exercising. There were four response options from "Not at all" to "Very Much." Parent fitness concerns were modeled as the average over the parents for whom this variable was reported. The test-retest correlation at EAT-I ranged from 0.68 to 0.70.

Friend Fitness Concern

At EAT-I and II participants responded to the prompt, "Many of my friends care about staying fit and exercising." There were four response options from "Not at all" to "Very Much." At Eat-III participants responded to the prompt, "My friends think it is important to be physically active." There were four response options from "strongly disagree" to "strongly agree." The test-retest correlations were 0.50 at EAT-I and 0.58 at

EAT-III. Although the wording is different at EAT-III these items were treated as measuring the same construct in the longitudinal analysis.

Analysis

Statistical tests comparing the analysis sample (n = 2902) to those lost to follow-up (n = 1844) showed significant differences between these groups on SES, ethnicity/race, gender, and baseline MVPA. To address differential loss to follow-up, data were weighted using the response propensity method in all analyses.[253] Response propensities (the probability of responding to any of the follow-up surveys) were estimated using a logistic regression on a large number of predictor variables from the baseline (EAT-I) survey. The weighting method resulted in estimates representative of the demographic make-up of the original sample, addressing the potential bias from differential loss to follow-up.

Generalized estimating equations (GEE) were used to estimate the association of age with MVPA over the 15 years of follow-up. To allow for potential non-linearity of the association, age was modelled as a five-level categorical variable except when testing for trends. To account for correlation of MVPA over follow-up within individuals, GEE models were fit using an auto-regressive working correlation matrix. Models were run in two steps. First, a model was run on the entire sample, adjusted for ethnicity/race, sex and SES, with a three way interaction for ethnicity/race and sex with age on MVPA to test for heterogeneity of the associations. When the test for three way interaction was statistically significant, models were run separately within eight strata defined by ethnicity/race and sex. For all models, tests for linear, quadratic and cubic trends in MVPA with age were run by sequentially adding age, age^2, and age^3 as continuous

variables to the model. Trends were considered significant at $p < 0.05$. Each model was run on the respondents from the sample of 2902 that were not missing any of the variables modeled (complete case analysis).

Generalized estimating equations were used next to estimate lagged (longitudinal) associations of the eight determinants with MVPA at five-year intervals. Since sports participation and parent fitness concerns were only measured at baseline (1999 – 2000), these determinants were modeled as baseline only; all other determinants were lagged five years and modeled as time-varying. To explore possible non-linearity in the association with MVPA, BMI was modelled both as a linear and as a quadratic determinant. All GEE models were fit with an auto-regressive working correlation matrix, and run on the entire sample and stratified by sex. Two way interactions for each determinant with ethnicity/race on MVPA, and with sex on MVPA and a three way interaction for ethnicity/race and sex with each determinant on MVPA were used to test for heterogeneity of the associations on the additive scale. If a determinant had a significant ($p < 0.05$) three way interaction with ethnicity/race and sex, models stratified on eight strata defined by ethnicity/race and sex were run. All models were also adjusted for age, SES and previous (five-year lagged) MVPA. Models run on the whole sample were also adjusted for ethnicity/race and sex. Analyses were conducted with the Statistical Analysis System (SAS, version 9.4, 2013, SAS Institute, Cary, NC, USA).

Results

Age Trends in MVPA

Mean reported MVPA declined by 2.1 hours per week over 15 years of follow-up in the overall sample from a mean of 6.4 hours per week at baseline (Table 18). The test

for the three-way interaction of ethnicity/race and sex with age on MVPA was statistically significant ($p<0.001$). Age trends in MVPA were, therefore, examined stratified by sex and ethnicity/race (Figures 23-25).

Compared to females, males showed higher MVPA at each age. A test for a cubic trend in MVPA with age was significant ($p < 0.001$) in males, indicating two periods of stability in MVPA with a period of more rapid change between. The trend in males showed stable MVPA over middle school and high school (7.4 hours per week [95% CI: 6.9 to 7.8]) before a comparatively steep decline at college age and stability at a lower level in young adulthood (5.2 hours per week [95% CI: 4.8 to 5.6]) (Figure 23).

Females showed a decline in MVPA from middle-school (6.1 hours per week [95% CI: 5.4 to 6.7]) into college-age and stabilized at lower levels during young adulthood (3.4 hours per week [95% CI: 2.9 to 3.9]) (Figure 23). The test for a quadratic trend in MVPA with age was significant ($p < 0.0001$) in females, providing evidence for this U-shaped curve, or period of rapid change followed by a period of stability.

Trends in MVPA with age also differed by ethnicity/race within each sex (Figures 24 and 25). Asian males report significantly lower levels of MVPA than white males ($p< 0.05$) at each age except for high school. There was a significant cubic, or S-shaped, trend in MVPA over age in white males, with stability from middle school to high school followed by relatively steep decrease in MVPA at college age and stability at a lower level in young adulthood (Figure 24). While smaller sample sizes in African-American and Hispanic males allow less precision in the MVPA estimates, tests for linear trends in MVPA with age were not significant, giving some evidence of greater stability in MVPA with age in these groups (Figure 24).

In middle school, white females report significantly greater levels of MVPA (6.8 hours per week [95% CI: 6.2 to 7.4]) than African-American (5.3 hours per week [95% CI: 4.1 to 6.5]) and Asian females (5.5 hours per week [95% CI: 4.5 to 6.4]). A significant quadratic trend in MVPA with age among white, African-American and Asian females indicates a steeper decline in MVPA from middle school to college age before stabilizing at lower levels as young adults (Figure 25). A significant linear trend in MVPA with age among Hispanic females indicates steady declines in MVPA from adolescence to adulthood (Figure 25).

Longitudinal Determinants of MVPA

In both males and females, the associations of five-year lagged depression, five-year lagged friend fitness concerns and baseline parent fitness concerns showed little evidence for any association (Table 19). Participating in any sports at baseline was associated with 0.46 more hours per week of MVPA per week at follow up in males and 0.44 more hours per week of MVPA per week females (Table 19). Males who responded "very much" to five-year lagged personal fitness concerns reported 1.28 more hours per week MVPA, while females that responded "very much" reported 0.56 more hours per week MVPA (Table 19). Five-year lagged screen-time showed a weak negative association with MVPA in both males and females (Table 19). Five-year lagged substance use showed a negative association with MVPA among females ($\beta = -0.38$) compared to a weaker, though slightly positive association with MVPA among males ($\beta = 0.27$) (Table 19).

The only determinant that differed significantly in its association with MVPA both by ethnicity/race and sex was BMI modeled as a quadratic or U-shaped association (test for

interaction: $p < 0.05$). Therefore, models of the association of BMI with MVPA were stratified by ethnicity/race within each sex.

Associations of BMI with MVPA

To further explore the form of the association of BMI *as a determinant of* MVPA, the sample was stratified into subgroups of ethnicity/race and sex and models of five-year lagged linear and quadratic BMI on MVPA were run. If quadratic terms were not statistically significant in these models ($p < 0.05$), they were dropped. Figure 26 shows the best fitting associations of five-year lagged BMI with MVPA in males and females respectively. Tests for trends for these associations were statistically significant at $p < 0.05$ in all subgroups except for African-American females.

White, African-American and Hispanic males show a linear decline in MVPA with increasing five-year lagged BMI. The steepest decline in MVPA with increasing five-year lagged BMI was among African-American males ($\beta = -0.25$ [95% CI: -0.41 to -0.09]) Among Asian males, the quadratic association of five-year lagged BMI with MVPA showed the best fit. In this group, MVPA was lower at both low high BMI, and higher MVPA at five-year lagged BMI between 25 and 30 kg/m^2 (Figure 4).

Among females there was a linearly decreasing association of five-year lagged BMI with MVPA in white females and no significant relationship of MVPA with five-year lagged BMI in African-American Females. As with Asian males, in Asian females there was a quadratic relationship of five-year lagged BMI with MVPA, who showed lower MVPA at both low and at high BMI, and higher MVPA at five-year lagged BMIs between 23 and 27 kg/m^2. The quadratic relationship of five-year lagged BMI with

MVPA in Hispanic females showed sharp declines in MVPA with BMI until it reaches a fairly low and stable level at BMI of 30 kg/m^2 (Figure 26).

Discussion

This study found that MVPA declined from adolescence to adulthood, and trends differed significantly by ethnicity/race and sex. Specifically, males showed later declines in MVPA than females. African-American and Hispanic males showed little evidence of change in MVPA behavior over follow-up. Asian males and females of non-white ethnicity/race started at lower levels of MVPA at middle school and declined into adulthood. The different timing of declines in MVPA among different groups may help in targeting interventions.

Five-year lagged personal fitness concerns and sports participation at baseline showed strong positive associations with MVPA over follow-up in both males and females. Reported substance use was associated with less MVPA five years later among females, but there was little evidence of a similar association among males. The only determinant that differed in its association with of MVPA behavior by ethnicity/race was five-year lagged BMI. Most racial and ethnic groups showed lower MVPA at higher lagged BMI; however Asians showed lower MVPA *both* at lower and at higher lagged BMI.

The strength of the association of sports participation in adolescence with MVPA into adulthood was similar for boys and girls and across racial and ethnic groups, indicating that interventions to promote participation on sports teams may have lasting benefits for meeting recommended levels of MVPA in all adolescents. The differing trends in MVPA across subgroups in our study provide some guidance about possible

mechanisms for the decline in MVPA and about when to target interventions. The later decline in MVPA among boys may be evidence of a biological mechanism leading to lower MVPA following puberty, however further studies will need to disentangle this from social mechanisms. The relatively sharp drop in MVPA among white boys after high school indicates that interventions in the transition to college and work may be the optimal timing, while the relatively low activity among Asian boys as early as middle school may mean that interventions need to be sustained from grade school through high school. MVPA starts at a lower level in adolescence among non-white females and declines quickly from adolescence to adulthood. Earlier interventions may, therefore, also be useful among non-white females. Previous work in college students by Nelson et al has similarly shown that while college may be an appropriate intervention point for white males and females, it may be too late for Asian males and non-white females.[254]

This study also found associations with determinants of MVPA that may be useful in understanding mechanisms and targeting interventions. BMI was the only determinant that differed significantly in its association with MVPA by ethnicity/race and sex. While BMI is often considered as an *outcome* of MVPA, the possible feedback loop makes it important to consider BMI also as a *determinant* of MVPA. We found 11 longitudinal studies that examined BMI as a determinant of physical activity.[8,194,185,203,199,255–260] Yet, none of these examined this association within subgroups of both sexes and multiple ethnicities/races. Examining these associations by ethnicity/race and sex showed that most racial and ethnic groups show lower MVPA at higher BMI. Among these groups, targeting interventions to increase MVPA to individuals with higher BMI may be useful. However, stratified models showed that Asian males and females at *lower* BMI also show

lower levels of MVPA. The Asian participants in this study were mostly Hmong ethnicity, a group largely comprised of families that immigrated to the United States relatively recently.[261] A potential mechanism for the association of low BMI with low MVPA in this group that should be studied further is that smaller Asian adolescents may not be participating in popular American team sports that favor larger individuals. Interventions to increase MVPA should not overlook these groups.

Other determinants of MVPA did not differ by ethnicity/race. Substance use inversely predicted MVPA among girls, in line with findings by Kimm et al, which found cigarette use inversely predicted physical activity in white adolescent girls.[199] Interestingly, this association did not exist among boys but the estimate and confidence interval among boys slightly favored a *positive* association.

Strengths and Limitations

A major strength of this study is its 15 years of longitudinal data collection. Following participants from adolescence to young adulthood allowed us to examine the shape of trends in MVPA over this period of rapid change. Further, having four waves of data collection allowed us to lag potential determinants of MVPA to establish evidence for temporality of any associations.

The diversity of this sample allowed us to examine trends and determinants of MVPA stratified by ethnicity/race and sex. These stratified analyses not only support previous longitudinal studies by clearly demonstrating that the decrease in MVPA occurs earlier among girls than among boys,[1,256] but also found that trends differ by ethnicity/race within strata of sex, expanding on previous cross-sectional work.[1] We are aware of only one other study that examined MVPA trends over development from

adolescence to young adulthood longitudinally within multiple subgroups of race and sex, though it only examined linear trends in physical activity.[262]

Since this population ranged from 11 to 18 years of age at baseline, our analyses could not completely separate cohort effect from the age effect. Future work will be needed to replicate these findings. Although selection bias may exist in these data due to differential loss to follow-up, our analyses used sampling weights to address this issue. In addition, demographic covariates and five-year lagged measurements of the outcome (MVPA) were added to models to address potential further bias due to confounding. However, it is possible that some residual bias from these sources remains. Since MVPA was self-reported in this study, measurement bias may exist. However, a validation sub-study at EAT-III showed that this self-report measure did not systematically over or underestimate MVPA when compared to accelerometer measures.[249] This finding was consistent even at high reported levels of MVPA.

Implications for Public Health

The results of this study can help target and tailor interventions to increase MVPA. Specifically, this study shows that interventions at earlier ages (for example, in primary school) may be needed for Asian boys and non-white girls. Many trials like GEMS,[54,36,52,56] TAAG,[58] and others[57,263,35,63,61] have focused on increasing MVPA among females, especially African American females. Yet, to our knowledge few trials have been developed to increase MVPA in Asian-American boys. The relatively low levels of MVPA at low BMIs among Asian males and females may mean that these groups should be targeted for tailored MVPA interventions – which are more commonly targeted at overweight individuals. Taken together with the association of sports

participation in adolescence with greater MVPA into adulthood, interventions that increase the diversity of sports offered at middle schools and high schools, especially focusing on sports that favor different body types, may engage more individuals and have a lasting impact on population levels of physical activity.

Tables

Table 18: Sample Descriptives for EAT-I through EAT-IV	
	Analysis Sample (n = 2902)
Age (Years): Mean (SD)	
EAT-I	14.8 (2.2)
EAT-II	19.4 (2.2)
EAT-III	25.2 (2.1)
EAT-IV	31.0 (2.1)
MVPA (Hours/Week): Mean (SD)	
EAT-I	6.4 (6.0)
EAT-II	5.3 (5.7)
EAT-III	4.2 (5.0)
EAT-IV	4.3 (4.6)
BMI (kg/m^2): Mean (SD)	
EAT-I	23.2 (6.4)
EAT-II	24.3 (6.3)
EAT-III	26.4 (7.3)
EAT-IV	27.8 (8.0)
Race-Gender Groups: n (weighted %)	
Male	1341 (50.0%)
White	853 (25.1%)
African American	122 (8.4%)
Hispanic	83 (4.3%)
Asian	221 (9.1%)
Mixed or Other	62 (3.0%)
Female	1561 (50.0%)
White	866 (22.4%)
African American	195 (10.4%)
Hispanic	93 (3.4%)
Asian	306 (10.0%)
Mixed or Other	101 (3.8%)
Socioeconomic Status (SES) at Baseline (EAT-I): n (weighted %)	
Low	388 (17.3%)
Low Middle	475 (18.8%)
Middle	726 (26.7%)
High Middle	772 (23.8%)
High	465 (13.5%)

Table 19: GEE Estimates of the Associations of Personal and Social Predictors with MVPA (Hours/Week) in EAT-I through EAT-IV

	Males (n = 1341)	Females (n = 1561)
TIME VARYING 5-YEAR LAGGED PREDICTORS		
	Estimate	**Estimate**
Screen-time (Unstandardized Beta [95% CI])		
Hours of Screen-time/week	-0.02 [-0.03 to -0.01]	-0.01 [-0.02 to -0.004]
Substance Use (Unstandardized Beta [95% CI])		
(2) Any	0.27 [-0.17 to 0.71]	-0.38 [-0.70 to -0.06]
(1) None	0 [Ref]	0 [Ref]
Personal Fitness Concerns (Unstandardized Beta [95% CI])		
(4) very much	1.28 [0.71 to 1.85]	0.56 [0.16 to 0.97]
(3) somewhat	0.22 [-0.33 to 0.78]	0.06 [-0.33 to 0.46]
(2) a little/not at all	0 [Ref]	0 [Ref]
Depression (Unstandardized Beta [95% CI])		
High Symptoms	-0.20 [-0.84 to 0.44]	-0.38 [-0.73 to -0.03]
Moderate Symptoms	-0.06 [-0.48 to 0.36]	-0.11 [-0.41 to 0.19]
Low Symptoms	0 [Ref]	0 [Ref]
Friend Fitness Concerns (Unstandardized Beta [95% CI])		
(4) Very Much	-0.07 [-0.88 to 0.74]	0.19 [-0.42 to 0.79]
(3) Much	-0.18 [-0.96 to 0.61]	0.09 [-0.48 to 0.67]
(2) Some	-0.83 [-1.66 to 0.01]	0.23 [-0.38 to 0.84]
(1) Little	0 [Ref]	0 [Ref]
BASELINE DETERMINANTS		
Sports Participation (Unstandardized Beta [95% CI])		
Any Sports	0.46 [0.02 to 0.90]	0.44 [0.16 to 0.74]
No Sports	0 [Ref]	0 [Ref]
Parent Fitness Concerns (Unstandardized Beta [95% CI])		
(4) Very Much	0.37 [-0.63 to 1.38]	0.42 [-0.19 to 1.03]
(3) Much	0.27 [-0.73 to 1.26]	0.12 [-0.46 to 0.70]
(2) Some	-0.04 [-1.06 to 0.99]	0.13 [-0.49 to 0.74]
(1) Little	0 [Ref]	0 [Ref]

[a]Models adjusted for race, age, SES and 5 year lagged MVPA

Figures

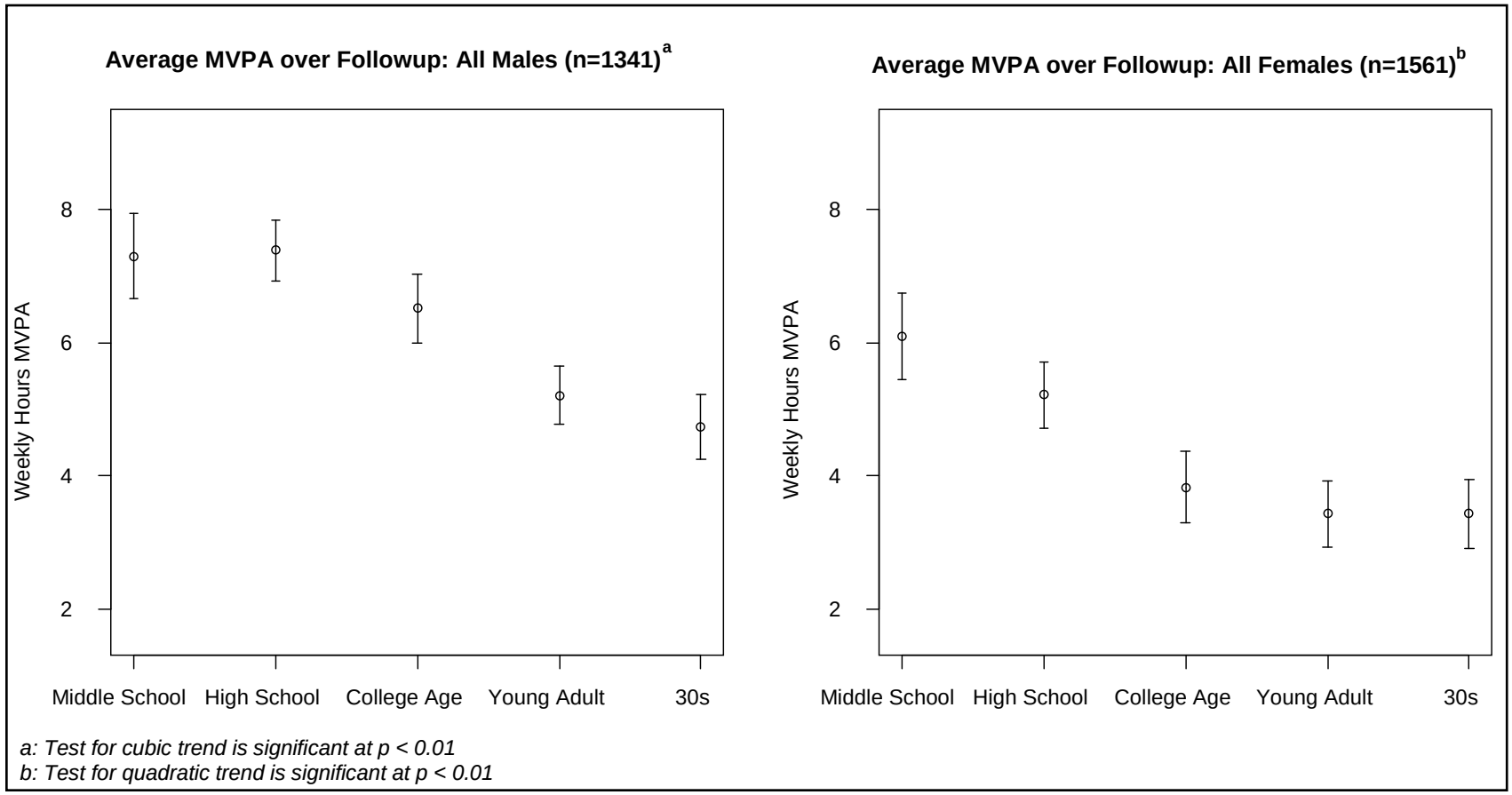

Figure 23: Age Trends in Population Mean MVPA (Hours/Week) for Males and Females in EAT-I through EAT-IV, adjusted for SES and Ethnicity/Race

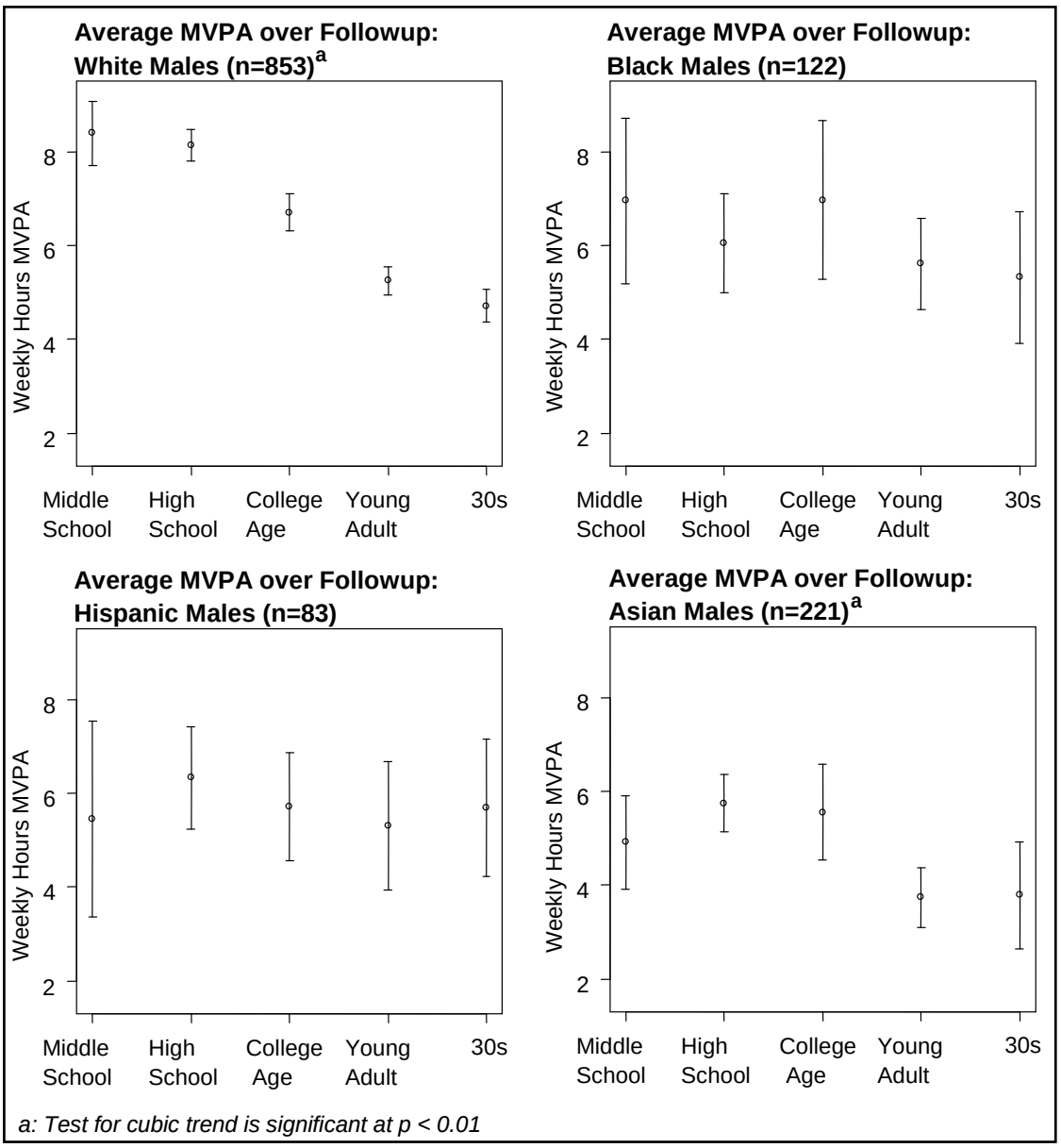

Figure 24: Age Trends in Population Mean MVPA (Hours/Week) for Males by Race in EAT-I through EAT-IV, adjusted for SES

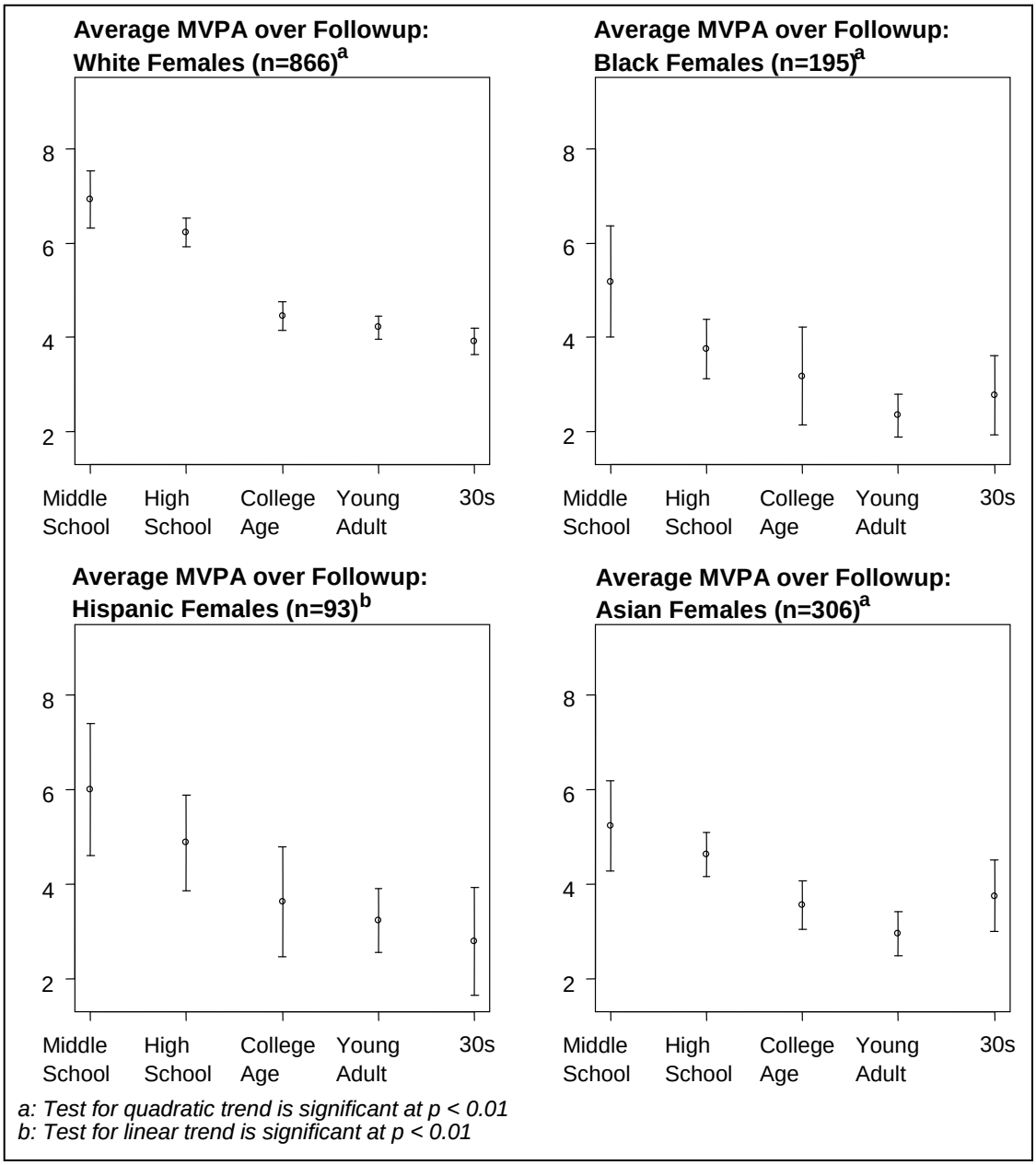

Figure 25: Age Trends in Population Mean MVPA (Hours/Week) for Females by Race in EAT-I through EAT-IV, adjusted for SES

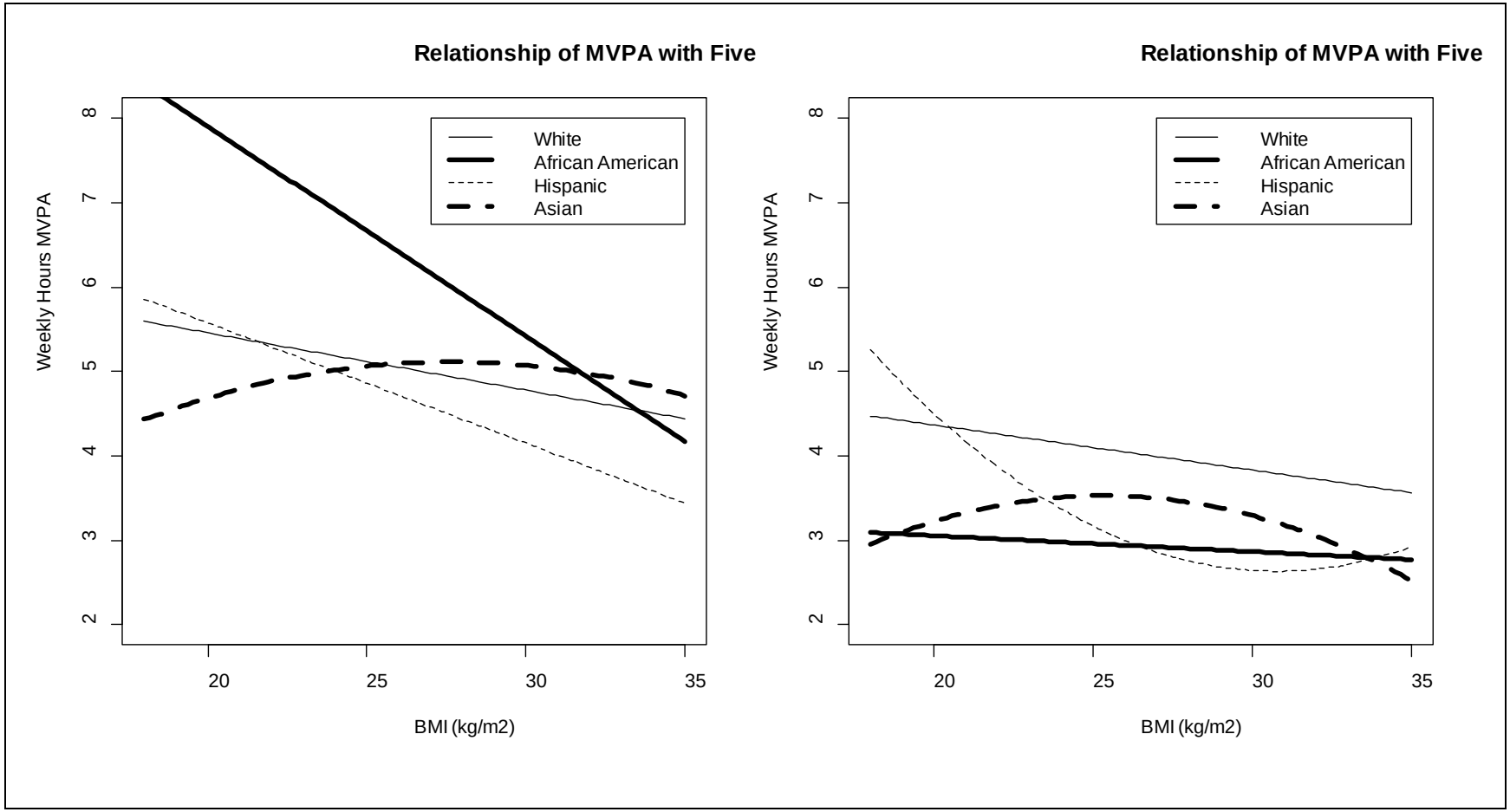

Figure 26: Predicted Forms of the Relationship of Five-Year Lagged BMI (kg/m2) on MVPA (Hours/Week) in EAT-I through EAT-IV

Chapter 8. Summary and Conclusions

The analyses presented in this study further our understanding of the development and maintenance of physical activity behavior. This study highlights the need to continue to examine detailed theories about the mechanisms behind the development of physical activity. This study also presents evidence that many of the determinants of physical activity do not vary across ethnic/racial groups in the population, but we did identify a few potentially important differences in determinants that should be studied further and considered when planning future interventions.

The determinants of physical activity are complex and future studies and interventions should be grounded in specific, detailed mechanistic theories about the development of this behavior in addition to being organized around social-ecological frameworks. Our factor analysis, presented in Manuscript 2, showed that factors across social-ecological levels may cluster together as strong determinants of physical activity. We found in particular that many social and personal determinants clustered together as strong predictors of moderate to vigorous physical activity in participants in the Project EAT-2010 cohort. Using Self-Determination Theory, we found evidence of increases in motivation to ski and exercise among participants in the Minne-Loppet Ski Program in Manuscript 1. Future studies will be needed to determine if the increases in motivation predict increases in physical activity behavior. Future implementations of the Minne-Loppet Ski Program should also continually strive to support all Self-Determination Theory constructs – particularly autonomy and relatedness, which were not as strongly supported as competence.

Encouragingly, we found few determinants of physical activity that differed by ethnicity/race. Evidence of consistency in the determinants of physical activity is useful when designing and implementing interventions, particularly when the interventions will be provided to diverse communities and there may not be sufficient resources to tailor the intervention to subgroups within a population. However, some differences in determinants of physical activity, like the neighborhood environment variables road connectivity and distance to trails among Asian and Hispanic girls in EAT-2010, did emerge that should be considered in future studies.

Relative to school based physical activity interventions, like the Minne-Loppet Ski Program, we also found a few differences in determinants of physical activity by ethnicity/race that should be considered further. We found in Manuscript 1 that motivation to exercise did not change among Hispanic participants in the Minne-Loppet Ski Program. Future studies with objective measures of physical activity and with developed process evaluation and dose received measures should be undertaken to confirm or refute this finding. Future implementations of the Minne-Loppet Ski Program should also be tested with incremental modifications that may make the program more accessible to all students – for example providing bi-lingual coaches.

While there were not enough Asian participants in the Minne-Loppet Ski Program surveyed to conduct subgroup analysis, it is important to ensure that the program and other physical activity interventions are reaching these participants. Findings from the Project-EAT cohorts with Asian student in the same school district as the Minne-Loppet Ski Program indicate that there may be unique determinants of physical activity among Asian student that need to be considered when designing and implementing interventions.

Specifically, results from the Project EAT-I through EAT-IV cohort reported in Manuscript 4 indicate that physical activity is already at a low level by middle school in Asian students and that Asian students at both a *low* and a *high* body mass index show lower levels of physical activity. Results from Project EAT-2010 reported in Manuscript 3 indicate that sports participation is not as strong of a determinant of physical activity in Asian males as it is in white, Hispanic and African American males.

The results from this study among Asian participants suggest several hypotheses for future study. First, physical activity interventions among Asian participants may need to be designed around activities other than sports. A second hypothesis, though, is that physical activity interventions among Asian participants may need to be designed around sports that are preferred by these participants. A corollary to this, based on our findings that *low* BMI predicted less physical activity in Asian participants, is that team sports that favor larger individuals may not be attractive to Asian students. Future physical activity interventions, particularly sport-focused interventions like the Minne-Loppet Ski Program, should consider these hypotheses.

The samples for these studies were all taken from the Twin Cities Metropolitan Area of Minnesota. Analyzing samples from the same geographic area allowed us to undertake subgroup analyses while having some confidence that potential confounders and effect modifiers like climate are controlled. While we do not expect that the findings from this study will be perfectly generalizable to other contexts, we do expect that some of the findings are useful for future studies. In particular we hope that we have provided more evidence that while many determinants of health behaviors are universal, there are

determinants that differ among subgroups within a population and these differences, as well as the consistencies, must be continually studied.

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Appendix A: Descriptions of Studies Identified in the Systematic Literature Review

Table A1: Trials that examine determinants of physical activity (PA) in unique subgroups defined by sex and race					
Study	Ages	Races	Sex (% Female)	PA Measure	Findings
Both Sexes, Multiple Races					
Frenn 2003[45] n = 130 Follow-Up: Not Reported Design: Quasi-Experiment GRT	12 to 15	African American, Native American, White	52%	Self-Report (CAAL 7 day recall)	African American, Hispanic, White and Asian Boys and Girls: Following a 6 session intervention that included 4 internet sessions, 1 snack preparation session and 1 gym session (50 minutes each), boys and girls in the intervention group showed less decrease in MVPA (-8.58 minutes) compared to boys and girls in the control group (-37.61 minutes) (p = 0.02).
Hannon 2005[49] n = 209 Follow-Up: 3 months Design: Quasi-Experiment GRT	High School	African American and White	49%	Pedometer (Yamax Digi-walker during PE class)	African American Girls: During gym classes, African American girls had fewer steps per minute than White girls regardless of whether the class was co-ed or split sex. This difference was the smallest during football classes. African American Boys: During gym classes, African American boys had fewer steps per minute than White boys. This difference was smallest for football and in football classes, steps per minute did not vary between co-ed and split sex classes. Steps per minute were much lower in split sex ultimate Frisbee (mean = 73.8) and soccer (mean = 67.3) classes than in co-ed ultimate Frisbee (mean = 98.4) and soccer classes (mean = 79.2). (All p for interactions by race and sex <0.002).
One Sex, Multiple Races					
Young 2006[61] n = 221 Follow-Up: 8 months Design: RCT	9th Grade	African American and White	100%	Self-Report (7 day recall)	African American and White Girls: Girls in an enhanced PE curriculum intervention – based on Social Action Theory and incorporating family workshops and monthly newsletters – did not differ significantly in MVPA from girls in a standard PE control group.
Webber 2008[58] n = 1721 to 3504 in 36 schools Follow-Up: 3 years Design: GRT	6th – 8th grade	African American, Hispanic, White	100%	Accelerometer (7 day, Hip worn Actigraph)	African American, Hispanic and White Girls: Girls in the TAAG intervention – a social-ecological intervention that included enhanced PE and Health curriculums and social marketing for PA throughout middle schools – showed no difference in PA from girls in standard curriculum control schools after 2 years of investigator led intervention. After the 3rd year,

Table A1: Trials that examine determinants of physical activity (PA) in unique subgroups defined by sex and race					
Study	Ages	Races	Sex (% Female)	PA Measure	Findings
					when a community or school based "Program Champion" took over administering the intervention, girls in the intervention schools showed 10.9 more MET weighted minutes of MVPA than girls in control schools (p = 0.03).
Both Sexes, One Races					
Wofford 2013[60] n = 46 Follow-Up: 3 months Design: Pre-Test, Post-Test	6 to 14	African American	39%	Self-Report (YRBS)	African American Boys and Girls: After 12 weeks of the CASTLES intervention – a 5 day per week, 3 hour per day afterschool intervention that includes nutrition lessons and PA activities – African American boys and girls reported 13.6 more minutes of MVPA than they had at baseline (p = 0.009).
Kerr 2013[51] n = 1654 Follow-Up: 1 year Design: RCT	14 to 16	African American	60%	Self-Report (YRBS)	African American Boys and Girls: African American boys and girls participating in the PHAT intervention – a 16 hour series of health lectures and activities delivered by trained facilitators over 2 Saturdays, which included a 2 hour module on PA – did not differ significantly in their MVPA than boys and girls in an attention control group.
Hatfield 2015[50] n = 93 Follow-Up: 8 months Design: Cross-over	8 to 14	Hispanic (91%)	45%	Pedometer (Walk4Life pedometer worn during intervention sessions)	Hispanic Girls: In a community based PA program that included both an exercise module and a sports module in each of its 59 sessions, Hispanic girls showed roughly 15 more pedometer steps per minute in the exercise module than they did in the sports module (p < 0.001).
One Sex, One Race					
Baranowski 2003[36] n = 35 Follow-Up: 3 months Design: RCT	8	African American	100%	Accelerometer (3 day, Hip worn CSA)	African American Girls: African American Girls who participated in the Houston GEMS intervention – a 4 week summer camp followed by 8 weeks of family internet sessions designed to increase PA and fruit and vegetable consumption – did not show significantly different MVPA from girls in an attention control.
Story 2003[56] n = 54 Follow-Up: 3 months Design: RCT	8 to 10	African American	100%	Accelerometer (3 day, Hip worn CSA)	African American Girls: African American Girls who participated in the Minnesota GEMS intervention – a 12 week afterschool program that included 24 one hour sessions, family worksheets and family events designed to increase PA and healthy eating –

Table A1: Trials that examine determinants of physical activity (PA) in unique subgroups defined by sex and race					
Study	Ages	Races	Sex (% Female)	PA Measure	Findings
					showed a non-significant trend towards more MVPA than girls in an attention control.
Robinson 2003[54] n = 61 Follow-Up: 3 months Design: RCT	8 to 10	African American	100%	Accelerometer (3 day, Hip worn CSA)	African American Girls: African American Girls who participated in the Stanford GEMS intervention – a 12 week community program that included 5 days per week of dance lessons and 5 to 6 home lessons on reducing TV viewing – showed 12% more minutes (not statistically significant) of MVPA than girls in an attention control.
Taymoori 2008[57] n = 161 Follow-Up: 1 year Design: GRT	Mean Age = 14.8	Iranian	100%	Self-Report (CAAL Previous day recall)	Iranian Girls: Two interventions were tested. Both interventions included four 60 minute sessions with group education and individual counseling. Four weeks after the sessions ended girls received a phone call counseling session. Two weeks after the phone session, all participants completed a mother-daughter mountaineering expedition. One intervention was based on the Health Promotion Model and one intervention was based on the Transtheoretical Model. Girls in both interventions showed significantly ($p < 0.005$) more mean minutes of PA per day at 1 year follow-up (13.8 more minutes for girls in the Transtheoretical Intervention and 10.5 more minutes for girls in the Health Promotion Intervention) than girls in a control group.
Olvera 2010[63] n = 46 Follow-Up: 3 months Design: RCT	7 to 13	Hispanic	100%	Accelerometer (2 day, Hip worn ActiCal)	Hispanic Girls: Girls in the BOUNCE intervention Pilot Study – a 12 week program with three 90 minute mother-daughter sessions per week that focused on nutrition and PA and were developed around Social Cognitive Theory – did not show any significant difference in average daily counts of MVPA than girls in a control group that received only one session per week.
Klesges 2010[52] n = 303 Follow-Up: 2 years Design: RCT	8 to 10	African American	100%	Accelerometer (3 day, Actigraph)	African American Girls: Girls in the Memphis GEMS intervention – a Social Cognitive Theory based intervention that included nutrition and PA education and met for 34 90-minute sessions at school and community locations (some were mother-daughter sessions) over two years – did not show significantly different minutes per day of MVPA than girls in an attention control intervention.
Thompson 2013[64]	12 to	African	100%	Self-Report	African American Girls:

Table A1: Trials that examine determinants of physical activity (PA) in unique subgroups defined by sex and race					
Study	Ages	Races	Sex (% Female)	PA Measure	Findings
n = 41 Follow-Up: 3 months Design: Pre-Test, Post-Test	18	American		(APARQ 7 day recall)	Girls in the FUN intervention – a Theory of Reasoned Action, church based, 12 week intervention that included one 60-minute session per week focused on education about PA and dance as an activity – did not show a significant difference in METs of PA at follow-up compared to baseline.
Arredondo 2014[35] n = 11 Follow-Up: 2 months Design: Pre-Test, Post-Test	8 to 12	Hispanic	100%	Parent Report (7 day frequency)	Hispanic Girls: Girls participating in an 8 week, church based intervention that included one 2.5-hour mother-daughter session per week based on Social Cognitive Theory and Family Systems Theory and focused strictly on PA, were reported by their mothers to be engaging in 1.4 more hours of PA per week after the intervention. Due to the small sample size, statistical significance was not tested.

Table A2: Cross Sectional Studies that examine determinants of physical activity (PA) in unique subgroups defined by sex and race					
Study	Ages	Races	Sex (% Female)	PA Measure	Findings
Both Sexes, Multiple Races					
Winnail 1995[177] n = 3437	9th – 12th Grade	African American and White	49%	Self-Report (YRBS)	Whites Males: Cigarette smoking (OR 2.0, CI: 1.4 to 2.9), marijuana use (OR 1.8, CI: 1.4 to 2.3) was associated with greater odds of being in the "low" active group compared to the "high" active group. Smokeless tobacco use (OR 1.6, CI: 1.1 to 2.4) was associated with greater odds of being in the "moderate" active group compared to the "high" active group. Black Females: Smokeless tobacco use was associated with greater odds of being in the "low" active group compared to the "high" active group (OR 364.2, CI: 161.9 to 819.1), but the high OR suggests too small a sample in this stratum. No other associations were significant.
Myers 1996[130] n = 995	9 – 15	African American and White	55%	Self-Report (SAPAC 24 Hour Recall)	Black and White Boys and Girls: PE class attendance was associated with more PA ($p < 0.0001$). Students who had recess reported 30 more minutes of total PA during the day ($p < 0.0001$). Sedentary Behavior was positively associated with PA ($r = 0.16$ for white males and females, $r = 0.33$ for black male, $r = 0.21$ for black females). Diastolic blood pressure showed a significant and linearly decreasing association with PA. Black Boys and Girls: Black boys and girls reported 5 minutes more PA ($p < 0.0001$) before school than white boys and girls. There was no difference in PA reported during and after school. Black Males: There was a significant but non-linear association of cholesterol with PA White Females: There was a significant but non-linear association of triglycerides with PA.

Table A2: Cross Sectional Studies that examine determinants of physical activity (PA) in unique subgroups defined by sex and race					
Study	Ages	Races	Sex (% Female)	PA Measure	Findings
Booth 2002[72] n = 2026	Year 8 and 10	Middle Eastern, Asian, White	47%	Self-Report (APARQ)	Middle Eastern, Asian and White Girls: During the winter there was 13.2% greater prevalence of high PA among high SES girls in 8th grade, and 20.7% greater prevalence of high PA among high SES girls in 10th grade (p = 0.02). Girls living in rural locations had 12.5% greater prevalence of PA in the summer than girls in urban locations in 8th grade and 10.2% greater prevalence in 10th grade (p = 0.02). White Boys: There was a non-significant, but greater prevalence of PA during summer among white boys than boys from other races. Asian Boys: There was a non-significant, but lower prevalence of PA during the winter among Asian boys than boys from other races.
Lowry 2002[117] n = 15394	9th - 12th Grade	African American, Hispanic, White	51%	Self-Report (YRBS)	White Females: Sedentary behavior (watching 2 or more hours of TV per day) was associated with greater odds (OR 1.7, CI: 1.3 to 2.1) of physical inactivity. Black Males: Sedentary behavior was associated with lower odds (OR 0.5, CI: 0.3 to 0.8) of physical inactivity.
McGuire 2002[121] n = 4746	7th - 12th Grade	African American, Hispanic, Asian, White	50%	Self-Report (Godin-Shepard)	African American, Hispanic, Asian and White Boys and Girls: PA is positively related to family fitness concerns (r = 0.2), friend fitness concerns (r = 0.1), personal fitness concerns (r = 0.4) and general health concerns (r = 0.2). African American, Hispanic, Asian and White Boys: PA is negatively related to weight concerns (r = -0.1) African American Boys: Personal fitness concerns were less strongly related to PA in African American Boys (r =0.27) compared to White (r = 0.47), Hispanic (r = 0.39) and Asian (r = 0.36) boys.

Table A2: Cross Sectional Studies that examine determinants of physical activity (PA) in unique subgroups defined by sex and race					
Study	Ages	Races	Sex (% Female)	PA Measure	Findings
McGuire 2002[120] n = 900	7th - 12th Grade	African American, Hispanic, Asian, White	53%	Self-Report (Godin-Shepard)	African American, Hispanic, Asian and White Boys and Girls: Perceived parent encouragement to be active was positively associated with PA (r = 0.26 for boys, r = 0.15 for girls). African American, Hispanic, Asian and White Girls: Parent reported encouragement to be active was positively associated with PA (r = 0.15). No difference was found among the races. African American and White Boys: Parental reported encouragement was positively related to PA (r = 0.39 in White and r = 0.26 in Black Boys). This association was not seen in Hispanic and Asian Boys.
Wardle 2003[171] n = 4320	11 to 12	African American, Asian, White	40%	Self-Report (Yes or no for participating in weekend exercise)	African American, Asian and White Girls: There was a significant, linearly decreasing trend of lower PA with more neighborhood deprivation (girls in the most deprived neighborhoods had 40% lower odds of engaging in weekend PA compared to girls in the least deprived neighborhoods). This association was weaker and non-significant among boys. No differences were observed between races.
Kitzman 2010[104] n = 669	6th Grade	African American, Other	56%	Accelerometer (7 day, Actical)	African American and Other Races, Boys and Girls: Self-efficacy was positively associated with PA (r = 0.15 in boys, r = 0.11 in girls). Boys and girls with higher BMI z-scores showed lower levels of PA (β = -6.0, p <0.0001). African American and Other Races, Boys: Family support is positively associated with PA for normal weight boys, but not for overweight or obese boys. This difference of association by BMI level is not seen in girls.
Taliaferro 2010[159] n = 72122	9th – 12th Grade	African American, Hispanic, White	51%	Self-Report (YRBS)	African American, Hispanic and White Boys and Girls: Boys and girls participating in sports had 3.6 times greater odds or reporting regular vigorous PA (CI: 3.3 to 3.9).

Table A2: Cross Sectional Studies that examine determinants of physical activity (PA) in unique subgroups defined by sex and race					
Study	Ages	Races	Sex (% Female)	PA Measure	Findings
Springer 2010[156] n = 22049	4th, 8th, 11th grade	Hispanic, Other	50%	Self-Report (YRBS)	Hispanic Girls: Compared to girls who spoke Spanish at home, Hispanic girls who spoke English at home had greater odds of engaging in vigorous PA on 3 or more days per week in 8th grade (OR = 1.25, CI: 1.03 to 1.52) and in 10th grade (OR = 1.42, CI: 1.10 to 1.83).
Ridgers 2011[146] n = 210	3rd – 6th Grade	African American, Hispanic and White	55%	Accelerometer (5 school days, Hip worn uniaxial Actigraph)	African American, Hispanic and White Boys: Boys spent 13.6% more of their recess time in MVPA than girls ($p < 0.001$) White Boys: Recess contributes more to White boys' total school day MVPA than for African American boys ($p < 0.01$) and more to White boys' total school day moderate activity than for Hispanic boys ($p = 0.03$). Hispanic Girls: Recess contributed mote to Hispanic girls' total school day sedentary time than for White or African American girls ($p < 0.01$)
Rosario 2014[148] n = 65871	12 to 18	African American, Hispanic, Asian, White	50%	Self-Report (YRBS)	African American, Hispanic, Asian and White Boys: Except among White and Hispanic boys younger than 15, being a sexual minority was associated with greater odds of physical inactivity for all races (ORs ranged from 1.6, CI: 1.1. to 2.3 for White and Hispanic boys older than 15 to an OR of 6.3, CI: 1.5 to 25.8 for African American boys younger than 15). Hispanic Girls: Hispanic sexual minority girls older than 15 were less likely to be physically inactive than non-sexual minorities (OR = 0.7, CI: 0.6 to 0.9). White Girls: White sexual minority girls older than 15 were more likely to be physically inactive than non-sexual minorities (OR = 1.2, CI: 1.0 to 1.5).
One Sex, Multiple Races					

Table A2: Cross Sectional Studies that examine determinants of physical activity (PA) in unique subgroups defined by sex and race					
Study	Ages	Races	Sex (% Female)	PA Measure	Findings
Bungum 1997[74] n = 852	14 – 18	African American and White	100%	Self-Report (7 day recall)	African American and White Girls: Support from fathers and participation in sports were positively associated with PA (βs not reported). Sedentary behavior was negatively associated with PA. African American Girls: Sports participation, friend support and father support all positively predicted PA (βs not reported). Following sports media negatively predicted PA. Caucasian Girls: Attitudes positively predicted PA (β not reported).
Bungum 1999[75] n = 738	14 - 18	African American and White	100%	Self-Report (7 day recall)	African American and White Girls: School sports participation and self-efficacy predicted moderate PA for both African American girls (un-standardized βs: 4.8 (p = 0.01) for school sports participation and 2.2 (p = 0.05) for self-efficacy) and White girls (βs: 4.7 (p = 0.01) for school sports participation and 4.5 (p = 0.05) for self-efficacy). African American Girls: Family support (β = 2.6, p = 0.01) and PA enjoyment (β = 1.6, p = 0.02) predicted moderate PA. School sports participation (β = 4.5, p = 0.0001) predicted vigorous PA. White Girls: Self-efficacy (β = 5.1, p = 0.0001) and barriers (β = 6.6, p = 0.001) predicted vigorous PA.
Motl 2001[127] n = 1797	Mean Age = 13.6	African American and White	100%	Self-Report (3 day recall)	African American and White Girls: Enjoyment of PA predicted MVPA (standardized β = 0.23, p < 0.05). Fitness predicted MVPA (standardized β = 0.17, p < 0.05). These relationships did not differ by race.
Felton 2002[88] n = 1668	8th Grade	African American and White	100%	Self-Report (3 day recall)	African-American Girls: Rural African American girls participated in 0.1 more 30 minute block per day of vigorous activity than urban African American girls (p = 0.05). White Girls: Urban White girls participated in 0.2 more 30 minute blocks per day of vigorous activity than rural White girls (p = 0.05).

Table A2: Cross Sectional Studies that examine determinants of physical activity (PA) in unique subgroups defined by sex and race					
Study	Ages	Races	Sex (% Female)	PA Measure	Findings
Motl 2002[128] n = 1797	Mean Age = 13.6	African American and White	100%	Self-Report (3 day recall)	African American and White Girls: Self-efficacy had direct effects on moderate PA (standardized $\beta = 0.24$, $p < 0.05$) and vigorous PA (standardized $\beta = 0.20$, $p < 0.05$). Perceived behavioral control had a direct effect on vigorous PA (standardized $\beta = 0.16$, $p < 0.05$). These associations did not differ by race.
Trost 2002[165] n = 2144	Mean Age = 13.6	African American and White	100%	Self-Report (3 day recall)	African American and White Girls: Self-efficacy and intention significantly predict MVPA (standardized βs: for White girls, $\beta = 0.17$ for intention and 0.19 for self-efficacy; for African American girls, $\beta = 0.17$ for intention and 0.09 for self-efficacy, all $p < 0.05$). African American Girls: In addition to self-efficacy and intention, perceived behavior control also predicts MVPA (standardized $\beta = 0.06$, $p = 0.04$).
Ward 2006[169] n = 1015	Mean Age = 14.6	African American and White	100%	Self-Report (3 day recall)	African American and White Girls: Perceived behavior control and sports team participation were positively associated with being classified as active compared to inactive (all $p < 0.01$, βs not reported). African American Girls: Social provisions, home exercise equipment and accessibility of parks or gyms were all positively associated with being classified as active (all $p < 0.05$, βs not reported). For normal weight African American Girls, self-efficacy and family support were also positively associated with being classified as active. White Girls: Self-efficacy, attitudes, enjoyment of PA and family support were all positively associated with being classified as active (all $p < 0.05$).

Table A2: Cross Sectional Studies that examine determinants of physical activity (PA) in unique subgroups defined by sex and race					
Study	Ages	Races	Sex (% Female)	PA Measure	Findings
Wilson 2007[176] n = 180	Mean = 13.6	Australian and Vietnamese	0%	Self-Report (3 day recall)	Asian and White Boys: Father support was associated with more vigorous PA per day (standardized β = 0.21 for White boys and β = 0.33 for Asian boys, all $p < 0.05$). Asian Boys: Father support was associated with more MVPA per day (standardized β = 0.40, $p = 0.01$) and more METs per day (standardized β = 0.53, $p = 0.002$). Father encouragement was associated with more MVPA per day (standardized β = 0.16, $p = 0.02$). White Boys: Mothers playing with them was associated with more vigorous PA per day (standardized β = 0.22, $p = 0.02$). Best friends playing with them was associated with more METs per day (standardized β = 0.27, $p = 0.03$).
Pate 2008[142] n = 1503	12th Grade	African American and White	100%	Self-Report (3 day recall)	African American and White Girls: BMI was associated with lower METs of PA (un-standardized β = -0.12, $p = 0.03$) and fewer 30 minute blocks of vigorous PA per day (β = -0.01, $p = 0.02$). Lower parent education (β = -0.09, $p = 0.04$) was associated with less and more commercial PA facilities (β = 0.09, $p = 0.02$) was associated with more vigorous PA per day. White Girls: More parks in the neighborhood was associated with higher METs of PA in a day (p for the interaction = 0.01).

Table A2: Cross Sectional Studies that examine determinants of physical activity (PA) in unique subgroups defined by sex and race					
Study	Ages	Races	Sex (% Female)	PA Measure	Findings
Wilson 2009[175] n = 113	Mean Age 13.9	Australian and Vietnamese	100%	Self-Report (3 day recall)	Asian Girls: Mothers playing with their daughters was associated with more METs per day (standardized β = 0.43) and more MVPA per day (β = 0.4). Teacher support was associated with more METs per day (β = 0.32) and father PA was associated with fewer METs per day (β = -0.23) (all $p < 0.05$). White Girls: Father support was associated with more METs of PA per day (β = 0.38). Mother encouragement was associated with more blocks of MVPA per day (β = 0.33). Teacher encouragement (β = 0.31) and mother help (β = 0.43) were associated with more blocks of vigorous PA per day, mothers playing with their daughters was associated with fewer blocks of vigorous PA per day (β = -0.34).
Kuo 2009[107] n = 1925	6th Grade	Hispanic, White, African American	100%	Self-Report (3 day recall)	African American and Hispanic Girls: African American girls and Hispanic girls reported more 30 minute blocks of PA at home or in the neighborhood (64.8% for African American, 63.2% for Hispanic than White (55%) or Asian (60.6%) girls, and more blocks of PA with another person (69.6% for African American, 62.8% for Hispanic) than White (56.1%) or Asian (54.5%) girls. White and Asian Girls: White and Asian girls reported more blocks of PA with organized groups (21.5% for White, 19.4% for Asian) than other African American (8.9%) or Hispanic (12.1%) girls. White Girls: White girls reported more blocks of PA at community facilities (36%) than other races (25.4 to 29.6%). Asian Girls: Asian girls reported more blocks of PA at school (14%) than other races (7.2 to 8.9%). All $p < 0.05$.

Table A2: Cross Sectional Studies that examine determinants of physical activity (PA) in unique subgroups defined by sex and race					
Study	Ages	Races	Sex (% Female)	PA Measure	Findings
Kelly 2010[99] n = 1366	6th Grade	African American, Hispanic, White	100%	Accelerometer (7days, Hip worn uniaxial Actigraph)	African American and White Girls: BMI was negatively associated with minutes of MVPA and vigorous PA (un-standardized β ranged from -0.02 to -0.03). Friend support was positively associated with minutes of MVPA and vigorous PA (un-standardized β ranged from 0.02 to 0.03). African American Girls: Teacher support was negatively associated with minutes of vigorous PA (un-standardized β = -0.03). Hispanic Girls: Transportation barriers were positively associated with minutes of MVPA (un-standardized β = 0.05). White Girls: Sports participation was positively associated with minutes of MVPA (un-standardized β = 0.03). Barriers were negatively associated with minutes of MVPA and vigorous PA (un-standardized β ranged from -0.01 to -0.02). All $p < 0.05$
Vangeepuram 2014[167] n = 1182	6 to 8	African American, Hispanic, Asian, White	100%	Pedometer (7 days, Yamax)	African American, Hispanic and White Girls: No association was found between asthma diagnosis and PA.
Hornby-Turner 2014[96] n = 145	9 to 11	Pakistani and British	100%	Accelerometer (5 days, Hip worn Actigraph)	Pakistani Girls: Pakistani girls were less active on weekend days and less active afterschool than White girls. This is shown in graphs of activity level by time of day, no statistical test is given.

Table A2: Cross Sectional Studies that examine determinants of physical activity (PA) in unique subgroups defined by sex and race					
Study	Ages	Races	Sex (% Female)	PA Measure	Findings
Duncan 2015[83] n = 353	10 to 14	African American, Hispanic, White	100%	Latent Variable (Accelerometer (7 days, Hip worn Actigraph) and Self-Report (YRBS))	African American, Hispanic and White Girls: Time in PE was positively associated with PA (unstandardized $\beta = 0.129$, $p < 0.01$). African American and White Girls: Active transportation was positively related to the PA latent variable in White girls ($\beta = 0.09$, $p < 0.05$), and to minutes of MVPA in African American girls ($\beta = 4.08$, $p < 0.001$) African American and Hispanic Girls: More PE enjoyment was associated with more recess PA in Black and Hispanic girls ($r = 0.27$, $p < 0.001$).
Both Sexes, One Race					
Kemper 1996[100] n = 110	10 – 12	Bolivian	53%	Heart-Rate Monitor (1 day, Polar Monitor)	Bolivian Boys and Girls: Low SES boys and girls spent 3-39 more minutes per day at 50-85% of the Heart Rate Reserve (Moderate PA) than high SES boys and girls. Bolivian Boys: The difference is activity between high and low SES boys is greater than the difference in activity between high and low SES girls.
Schmidt 1998[151] n = 1579	6 – 18	Singaporean	54%	Self-Report (Singapore Youth Coronary Risk and Physical Activity Study.)	Singaporean Boys and Girls: Greater sports participation was associated with more PA (based on visual trend, no significance reported) Singaporean Girls: Girls in the most active quintile reported less sedentary behavior than boys in the most active quintile ($p < 0.001$). Percent body fat ($r = -0.22$, $p = 0.001$) and blood pressure ($r = -0.12$, $p = 0.03$) were negatively associated with PA. Singaporean Boys: PA was negatively associated with cholesterol ($r = -0.13$, $p = 0.02$) and triglycerides ($r = 10.18$, $p = 0.001$).

Table A2: Cross Sectional Studies that examine determinants of physical activity (PA) in unique subgroups defined by sex and race					
Study	Ages	Races	Sex (% Female)	PA Measure	Findings
Trost 1999[166] n = 108	Mean Age = 11.4	African American	55%	Accelerometer (7 days, Hip worn CSA)	African American Boys and Girls: High active boys and girls had greater self-efficacy scores than low active boys and girls (score difference: 0.3 for boys, 0.2 for girls, $p = 0.01$). African American Boys: High active boys had greater sports participation than low active boys (score difference: 1.7, $p = 0.001$). More high active boys perceived their mother as active (72%) than low active boys (33%, $p < 0.05$). African American Girls: High active girls had more positive outcome beliefs than low active girls (score difference: 0.02, $p = 0.008$). Fewer high active girls watched more than 3 hours of TV per day (41%) than low active girls (72%, $p < 0.05$).
Guinn 2000[94] n = 234	Mean Age = 13.4	Hispanic	50%	Self-Report (Public Health Service Activity Index)	Hispanic Boys and Girls: Task-orientation accounted for 12% of the variance in PA participation. Self-esteem and ego-orientation accounted for less than 1% of the variance in PA participation.
Page 2003[139] n = 2665	15 - 21	Taiwanese	39%	Self-Report (YRBS)	Asian Boys and Girls: Loneliness scores were lower for high active boys (mean score = 38.4) and girls (mean score = 35) than for inactive boys (mean score = 44.9) and girls (mean score = 40.9) (all $p < 0.05$). Shyness scores were lower for high active boys (mean score = 15.8) and girls (mean score = 14.3) than for inactive boys (mean score = 18.2) and girls (mean score = 18) (all $p < 0.05$). Hopelessness scores were lower for high active boys (mean score = 5.2) and girls (mean score = 4.2) than for inactive boys (mean score = 7.4) and girls (mean score = 7) (all $p < 0.05$).
Wu 2003[179] n = 832	12 to 15	Taiwanese	45%	Self-Report (5 day activity log)	Asian Boys and Girls: Self-efficacy had the strongest direct association with PA (standardized $\beta = 0.33$ for boys, 0.32 for girls). Peer influences also had a direct effect on PA (standardized $\beta = 0.2$ for boys, 0.26 for girls). Perceived barriers had an indirect association with PA through self-efficacy, and peer influences had an indirect effect through perceived barriers and self-efficacy (βs for the indirect effects not reported). All $p < 0.05$.

Table A2: Cross Sectional Studies that examine determinants of physical activity (PA) in unique subgroups defined by sex and race					
Study	Ages	Races	Sex (% Female)	PA Measure	Findings
Gomez 2004[91] n = 177	7th Grade	Hispanic	57%	Self-Report (Project PACT questionnaire)	Hispanic Boys: Greater distances to open play areas was associated with lower outdoor PA (β = -0.32, p = 0.006). Hispanic Girls: Violent crimes in the neighborhood was associated with lower outdoor PA (β = -0.34, p <0.001). Perceived neighborhood safety was associated with more outdoor PA (β = 0.22, p = 0.02).
Taveras 2004[161] n = 11606	9 to 16	White	56%	Self-Report (Growing Up Today Survey)	White Boys and Girls: A 1 category increase in "Wanting to look like media figures" was associated with more hours per week of total PA (β = 0.4 for girls and 1.0 for boys, p < 0.01). This association was stronger in older boys and girls and in girls that were not concerned with weight. Athletic self-esteem (scale: 9-18, β = 1.0 for girls and 0.9 for boys, p <0.01), social self-esteem (scale: 9-18, β = 0.3 for girls and 0.4 for boys, p <0.01), and trying to lose weight (scale: binary, β = 1.4 for girls and 0.9 for boys, p <0.05) were associated with more hours per week of total PA. White Boys: Peer fitness importance (scale: 1-5, β = 0.5, p <0.01) and peer weight concerns (scale: 1-5, β = 1.1, p <0.01) were associated with more hours per week of total PA. White Girls: Peer influences to be thin (scale: 1-5, β = 0.9, p <0.01) and adult influences to be thin (scale: 1-5, β = 0.5, p <0.01) were associated with more hours per week of total PA.

Table A2: Cross Sectional Studies that examine determinants of physical activity (PA) in unique subgroups defined by sex and race					
Study	Ages	Races	Sex (% Female)	PA Measure	Findings
Li 2006[112] n = 1787	11 to 17	Chinese	50%	Self-Report (unspecified recall)	Asian Boys and Girls: Holding school sports meeting only once every 2 years was associated with 50% (boys) and 70% (girls) greater odds of being inactive (less than 150 minutes per week moderate activity or less than 60 minutes per week vigorous activity) compared to holding sports meetings twice per year. ($p < 0.5$) Asian Boys: Traveling to school by automobile (OR = 3.2), no class recess OR = 2.2), and lack of vacant fields (OR = 1.7) or video game shops (OR = 1.5) near the house were associated with greater odds of being inactive (all $p < 0.05$). Going to a school (OR = 0.4) that did not allow bike riding, and having a parent that exercises with the boy (OR = 0.6) were associated with lower odds of being inactive (all $p < 0.05$). Asian Girls: Two PE sessions per week compared to one (OR = 2.1) and lack of sidewalks around the house (OR = 1.5) were associated with greater odds of being inactive (all $p < 0.05$). Having sports meetings that lasted more than 3 days (OR = 0.5), living with more than 3 family members (OR = 0.4), having a father with Secondary or greater education (OR = 0.5) and having a non-working mother (OR = 0.6) were associated with lower odds of being inactive (all $p < 0.05$).
Bastos 2008[69] n = 857	10 to 19	Brazilian	.	Self-Report validated with pedometer (Short form of Pelotas Birth Cohort Study Questionnaire, Digi Walker pedometer)	Brazilian Boys: Boys from lower SES levels had 26% greater likelihood of being inactive (less than 300 minutes per week of activity) ($p = 0.04$). Boys with active mothers had 23% lower likelihood of being inactive ($p = 0.02$). Boys with former smoker mothers had 29% lower likelihood of being inactive compared to boys with never smoker mothers ($p = 0.04$). Brazilian Girls: Girls with active fathers had 22% greater likelihood of being inactive ($p = 0.04$).

Table A2: Cross Sectional Studies that examine determinants of physical activity (PA) in unique subgroups defined by sex and race					
Study	Ages	Races	Sex (% Female)	PA Measure	Findings
Seabra 2008[152] n = 2375	Mean age ~ 16	Portuguese	49%	Self-Report (Baecke questionnaire)	Portuguese Boys and Girls: The PA of boys and girls was more strongly correlated to their siblings (r^2 ranged from 0.21 to 0.26) than to their parents (r^2 ranged from 0.05 to 0.12). Portuguese Girls: The PA of girls correlated more with their mothers (r^2 = 0.18) than that of boys (r^2 = 0.12). Portuguese Boys: The PA of boys correlated more with their fathers (r^2 = 0.12) than that of girls (r^2 = 0.05).
Santos 2009[150] n = 1124	12 – 18	Portuguese	53%	Self-Report (Mota questionnaire)	Portuguese Girls: Availability of low cost recreation facilities in the neighborhood was associated with greater odds of being active (OR =1.44, p = 0.05). Portuguese Boys: Presence of people being active in the neighborhood was associated with greater odds of being active (OR =1.59, p = 0.03).
Patnode 2010[144] n = 294	7 to 10	White (93%)	49%	Accelerometer (7 day, Hip worn Actigraph)	White Girls: Distance to the school they attend is negatively associated with MVPA (standardized β = -0.2, p < 0.05). White Boys: Peer support (standardized β = 0.19, p < 0.05), home PA equipment (standardized β = 0.18, p < 0.05) and temperature (standardized β = 0.21, p < 0.05) were positively associated with MVPA.
Lee 2010[108] n = 1814	Mean Age = 14.4	Singaporean	49%	Self-Report (3 day recall)	Singaporean Boys and Girls: METs of PA was predicted by self-efficacy (standardized β = 0.15 for boys and 0.07 for girls), PA enjoyment (standardized β = 0.1 for boys and 0.08 for girls), parental support (standardized β = 0.08 for boys and 0.13 for girls) and sports participation (standardized β = 0.08 for boys and girls) (all p < 0.05). Singaporean Girls: METs of PA was predicted also by home sports equipment (standardized β = 0.09, p < 0.05).

Table A2: Cross Sectional Studies that examine determinants of physical activity (PA) in unique subgroups defined by sex and race					
Study	Ages	Races	Sex (% Female)	PA Measure	Findings
Oliver 2011[135] n = 393	6	Pacific (New Zealand)	60%	Accelerometer (8 day, ActiCal)	Pacific Ethnic Boys and Girls: Higher percent of time spent in MVPA was associated with maternal PA (β = 0.03 [CI: 0.01 to 0.05] for high maternal PA compared to low maternal PA), hours of sunshine (β = 0.002 [CI: 0.001 to 0.004]), and whether it was raining (β = -0.02 [CI -0.03 to -0.01] for rainy days).
de Farias Junior 2011[78] n = 2874	14 to 19	Brazilian	58%	Self-Report (Frequency and Duration Recall)	Brazilian Boys and Girls: Living close to destinations was associated with getting more than 300 minutes per week of MVPA (OR = 1.96 [CI: 1.4 to 2.8] among boys and 1.33 [CI: 1.1 to 1.7] among girls). Brazilian Boys: Having other adolescents in the neighborhood that are active was associated with getting more than 300 minutes per week of MVPA (OR = 1.2 [CI: 1.1 to 1.6].
Malina 2011[118] n = 688	6 to 13	Mexican	50%	Self-Report (Steps to School and Daily Chores)	Mexican Boys and Girls: Stunted, overweight and normal weight boys and girls did not differ in terms of their daily steps to school or daily chores.
Olvera 2011[136] n = 51	Mean = 10	Hispanic	61%	Accelerometer (7 day, Hip worn accelerometer)	Hispanic Boys and Girls: Maternal PA was significantly and positively correlated with MVPA in boys and girls (r^2 = 0.17, p = 0.002). Boys and girls with high accultured mothers reported 19.5 fewer minutes of MVPA than boys and girls with low accultured mothers (p = 0.01).

Table A2: Cross Sectional Studies that examine determinants of physical activity (PA) in unique subgroups defined by sex and race					
Study	Ages	Races	Sex (% Female)	PA Measure	Findings
Perry 2011[145] n = 773	6th - 8th grade	Latino	51%	Self-Report (YRBS)	Hispanic Boys and Girls: Participation in after school activities (OR = 1.3 [CI: 1.1 to 1.6] for girls and OR = 1.6 [CI: 1.3 to 1.9] for boys) and in 5 days per week of PE class (OR = 3.5 [CI: 1.9 to 6.4] for girls and OR = 4.0 [CI: 2.3 to 6.8] for boys) was associated with getting 60 minutes or more of MVPA on 5 or more days a week for both sexes. Hispanic Girls: Having family (OR = 1.7 [CI: 1.0 to 2.9]) and team (OR = 2.3 [CI: 1.2 to 4.5]) as a source of motivation was associated with getting 60 minutes or more of MVPA on 5 or more days a week. Hispanic Boys: Marijuana use (OR = 0.31 [CI: 0.1 to 0.9]) was negatively associated with getting 60 minutes or more of MVPA on 5 or more days a week.
Oh 2012[134] n = 101	12 to 19	Hispanic	57%	Pedometer (7 day New Lifestyles pedometer)	Hispanic Boys and Girls: Hispanic boys and girls had 10.4 and 15.9 fewer minutes respectively of MVPA on the weekend then on the weekday (significance level was not reported). MVPA did not differ between Mexican and US born boys and girls.

Table A2: Cross Sectional Studies that examine determinants of physical activity (PA) in unique subgroups defined by sex and race					
Study	Ages	Races	Sex (% Female)	PA Measure	Findings
Strong 2012[157] n = 1154	12 to 17	Hispanic	50%	Self-Report (YRBS)	Hispanic Boys and Girls: Participation in 5 days a week of PE was associated with having 60 minutes or more of MVPA on 4 days in both school and community settings for boys (ORs 2.5 to 3.3) and girls (ORs 2.5 to 3.6) and with having 20 minutes or more of vigorous PA on 3 days per week in school settings (OR = 3.5 for boys and girls) (all $p < 0.05$). Hispanic Boys: Participation in 5 days a week of PE was also associated with having 20 minutes or more of vigorous PA on 3 days per week in community settings (OR = 3.0, $p < 0.05$). Having a BMI greater than the 95th percentile (OR = 0.6, $p < 0.05$) and watching more than 2 hours of TV per day (OR = 0.6, $p < 0.05$) were negatively associated with having 60 minutes or more of MVPA on 4 days community settings. Having parents with more than a high school education was associated with having 60 minutes or more of MVPA on 4 days in both school and community settings (ORs 1.7 to 1.9) and with having 20 minutes or more of vigorous PA on 3 days per week in school settings (OR = 1.9, all $p < 0.05$). Higher parent acculturation score was associated with having 60 minutes or more of MVPA on 4 days school settings (OR = 1.4, $p < 0.05$). Hispanic Girls: Watching more than 2 hours of TV per day was negatively associated with having 60 minutes or more of MVPA on 4 days school settings (OR = 0.5) and with having 20 minutes or more of vigorous PA on 3 days per week in school (OR = 0.6) and community (OR = 0.5) settings (all $p < 0.05$).
Wilkinson 2012[174] n = 1154	12 to 17	Hispanic	50%	Self-Report (YRBS)	Hispanic Boys: Boys who reported having 60 minutes of MVPA on 5 days per week reported higher scores on the thrill and adventure seeking (1.0 unit higher score, $p < 0.001$) and on the social disinhibition (0.4 unit higher score, $p = 0.006$) subscales of the sensation seeking scale than boys who reported less MVPA.

Table A2: Cross Sectional Studies that examine determinants of physical activity (PA) in unique subgroups defined by sex and race					
Study	Ages	Races	Sex (% Female)	PA Measure	Findings
Baskin 2013[68] n = 116	12 to 16	African American	53%	Accelerometer (7 day, Hip worn Actigraph)	African American Boys: A one unit increment in self-efficacy was associated with a 16.91 minute increment in daily MVPA (p = 0.02). African American Girls: A one unit increment in family social support was associated with a 1.65 minute increment in daily MVPA (p <0.0001).
Roman 2013[147] n = 386	6th – 12th Grade	Latino	53%	Self-Report (Active Where? Survey)	Hispanic Boys: Fear of crime was negatively associated with PA (standardized β = -0.3, p < 0.05) Hispanic Girls: SES was positively associated with PA (standardized β = 0.2, p < 0.05)
Tate 2015[160] n = 145	15 to 17	African American	61%	Self-Report (PAQ-A)	African American Boys and Girls: PA did not differ between suburban, high SES respondents and urban, low SES respondents.
One Sex, One Race					
Ward 1997[170] n = 150	5th Grade	African American	100%	Self-Report (Previous Day Recall)	African American Girls: Obese girls reported 0.4 fewer 30 minute blocks of vigorous PA and 0.5 fewer blocks of MVPA per day than non-obese girls (both p < 0.05). Percent body fat measured at tricep skinfold was correlated with vigorous PA (Spearman's r = -0.19, p <0.05) and MVPA (Spearman's r = -0.22, p <0.05).
Kerner 2001[102] n = 295	Mean Age = 14	African American	100%	Self-Report (7 day recall)	African American Girls: There was no correlation between PA and Internet Use. Among internet non-users, there was a positive correlation between attitudes and weekly PA (r = 0.21, p < 0.01).
Adkins 2004[66] n = 52	8 to 10	African American	100%	Accelerometer (3 day CSA)	African American Girls: Simple Correlations showed BMI (r = -0.35, p = 0.01) and Parental Self-Efficacy for PA with Daughter (r = 0.45, p = 0.001) were significantly related to girls' PA. Parent Reported Parental Support (r = 0.26, p = 0.06) was near-significantly related. Girls' perceptions of support, neighborhood safety, access to facilities and family environment were not related to girls' PA.

Table A2: Cross Sectional Studies that examine determinants of physical activity (PA) in unique subgroups defined by sex and race					
Study	Ages	Races	Sex (% Female)	PA Measure	Findings
Beech 2004[70] n = 209	8 to 10	African American	100%	Accelerometer (3 day ActiGraph)	African American Girls: Parent Cultural Identity was unrelated to girls' PA overall. However, within study centers, relationships were seen where in Memphis, mothers' global cultural identity negatively predicted girls' PA ($r = -0.26$, $p = 0.04$), while in Stanford, mothers' global cultural identity positively predicted girls' PA ($r = 0.31$, $p = 0.02$).
Nichols-English 2006[133] n = 133	8 – 12	African American	100%	Self-Report (7 day recall)	African American Girls: There was no effect of mothers' modeling of moderate PA on girls' moderate PA. However, mothers' modeling of vigorous PA negatively predicted girls' vigorous PA ($r = -0.16$, $p < 0.05$). Mothers' and girls' BMI and PA beliefs were not associated with girls' PA. SES, measured by mothers' education was not associated with girls' PA.
Groth 2011[93] n = 511	15 to 19	African American	100%	Self-Report (Weekly frequency)	African American Girls: Intentions to consume healthy foods was positively related to PA ($\beta = 0.183$, $p < 0.001$).
Foran 2013[89] n = 326	Middle School	Hispanic	100%	Self-Report (Abstract only: instrument not reported)	Hispanic Girls: More active girls had higher social support, motivation and positive meanings of PA. Less active girls had more screen time.

Table A3: Longitudinal Studies that examine determinants of physical activity (PA) in unique subgroups defined by sex and race					
Study	Age (Baseline)	Races	Sex (% Female)	PA Measure	Findings
Both Sexes, Multiple Races					
Sagatun 2008[207] n = 2489 Follow-up: 3 years	10th Grade	Norwegian and Ethnic Minority	55%	Self-Report (Weekly frequency) validated by Actigraph accelerometer	Norwegian and Ethnic Minority Boys: Physical activity decreased more over three year follow up in boys whose father reported low income compare to boys whose father reported high income (β = -0.90 [CI: -1.66 to -0.14]). No difference was found between ethnicities. Norwegian and Ethnic Minority Girls: Physical activity decreased more over three year follow up in girls whose mother reported low education compare to girls whose mother reported high education (β = -0.75 [CI: -1.38 to -0.12]). No difference was found between ethnicities.
Taverno-Ross 2014[209] n = 2264 Follow-up: 10 years	Mean = 14.9	Foreign and Non-Foreign Born	55%	Self-Report (Godin-Shepard)	This study does not really address race, but it is from Project Eat, so is included. Foreign Born boys and girls showed less PA than Native Born boys and girls (0.6 hours per week less for girls and 1.9 hours per week less for boys in young adulthood). The changes in PA over time were not different between foreign born and native born.
Kelly 2012[183] n = 404	13 to 18	Minority and White	53%	Self-Report	White and Non-White Boys and Girls: There is a direct path between cognitive-behavioral skills and PA (standardized β = 0.15). There are indirect paths for knowledge, social motivation and personal motivation through cognitive-behavioral skills to PA (total β not reported). Neighborhood safety and school have an indirect relationship with PA through knowledge and cognitive-behavioral skills (total β not reported). Non-White Girls: The Information Motivation Behavior (total) model predicts less of the variance in PA (r^2 = 0.05) for non-White girls than for non-White boys (r^2 = 0.11) or for White boys and girls (r^2 = 0.13).
One Sex, Multiple Races					
Kimm 2002[199] n = 1379 Follow-up: 10 years	9 - 10 (Baseline)	African American and White	100%	Self-Report (HAQ) validated by	African American and White Girls: From ages 9 to 17, initial BMI (unstandardized β = -0.17 [9 to 14] and -0.08 [14 to 17] for African American girls and -0.21 [9 to 14] and -0.08 [14 to 17] for

Table A3: Longitudinal Studies that examine determinants of physical activity (PA) in unique subgroups defined by sex and race					
Study	Age (Baseline)	Races	Sex (% Female)	PA Measure	Findings
				accelerometer	White girls) and initial PA (unstandardized β = -0.79 [9 to 14] and -0.43 [14 to 17] for African American girls and -0.82 [9 to 14] and -0.35 [14 to 17] for White girls) were negatively associated with METs of PA at follow-up. Income was not associated with PA. African American Girls: Parent education was associated with METs of PA from ages 14 to 17 only (unstandardized β = -1.28 for high-school compared to college). Pregnancy was negatively associated with METs of PA from ages 14 to 17 (unstandardized β = -1.91) White Girls: Parent education was associated with METs of PA from ages 9 to 17 (unstandardized β = -4.34 [ages 9 to 14] and -1.80 [ages 14 to 17] for high-school compared to college). Living in a single parent household was negatively associated with METs of PA from ages 14 to 17. Smoking was negatively associated with METs of PA from ages 14 to 17 (unstandardized β = -1.89).
Motl 2005[204] n = 1038 Follow-up: 1 year	Mean Age = 13.6	African American and White	100%	Self-Report (3 Day recall)	African American and White Girls: Self-efficacy was associated with Moderate (standardized β = 0.34) and Vigorous (standardized β = 0.17) PA at time 1. Perceived behavior control was associated with Vigorous PA at time 1 (standardized β = 0.25) and time 2 (standardized β = 0.15). Previous PA was associated with MVPA (standardized β = 0.39) and vigorous PA (standardized β = 0.36) at follow-up. Lagged effects of self-efficacy and perceived behavior control at time 1 on PA at time 2 were not reported. The associations did not vary by race.
Dowda 2007[194] n = 421 Follow-up: 5 years	8th Grade	African American and White	100%	Self-Report (3 Day recall)	African American and White Girls: Higher METs of PA were associated with higher family support (un-standardized β = 1.8), perceived behavior control (un-standardized β = 1.5), and self-efficacy (un-standardized β = 1.0). It is not clear if these were lagged effects. BMI and SES did not show associations with PA African American Girls: Maintaining family support was associated with increased METs of PA.

Table A3: Longitudinal Studies that examine determinants of physical activity (PA) in unique subgroups defined by sex and race					
Study	Age (Baseline)	Races	Sex (% Female)	PA Measure	Findings
					White Girls: Maintaining family support was associated with decreased METs of PA.
Dishman 2009[193] n = 195 Follow-up: 4 years	8th Grade	African American and White	100%	Self-Report (3 Day recall)	African American and White Girls: Social support at 8th grade had a direct effect on PA at 8th grade (standardized β = 0.52). Change in social support between 8th and 12th grades had a direct effect on change in PA (standardized β = 0.21). Self-Efficacy at 8th grade had an indirect effect on PA at 8th grade through social support (standardized β = 0.44). Self-Efficacy at 8th grade moderated the association of change in social support with change in PA. High Self-Efficacy and little change in social support were associated with the smallest declines in PA. These relationships did not differ by race.
Madsen 2009[203] n = 1379 Follow-up: 9 years	9 – 10 at Baseline	African American and White	100%	Self-Report (HAQ)	African American and White Girls: African American race was consistently the strongest predictor of METs of PA (β ranged from -0.09 to -0.21 over 5 waves of follow-up. Parental education was also a strong predictor (β ranged from 0.04 to 0.19 over 5 waves). Lagged perceived parental modeling showed a weak (β ranged from 0.01 to 0.09) but often significant association with girls' METs of PA. Sedentary behavior was generally negatively associated with PA and attitude positively associated with PA, though neither was consistently significant at all time-points. The association with parental modeling did not differ by race except at the last wave of follow-up, where there was a slightly weaker association for African American Girls.
Dishman 2010[192] n = 972 Follow-up: 2 years	6th and 8th Grade	African American, Hispanic, Asian, Native American, White	100%	Accelerometer (7 day, Hip worn ActiGraph)	African American, Hispanic, Asian, Native American and White Girls: Physical activity did not significantly differ between 6th grade and 8th grade. Change in PA was negatively predicted by initial PA (standardized β = -0.54, $p < 0.001$) African American, Hispanic and White Girls: Self-Efficacy at 8th grade had a direct effect on PA at 8th grade (standardized β = 0.11). Perceived barriers at 8th grade had a direct effect on PA at 8th grade (standardized β = -0.08). Self-Efficacy (standardized β = 0.03) and Social

Table A3: Longitudinal Studies that examine determinants of physical activity (PA) in unique subgroups defined by sex and race					
Study	Age (Baseline)	Races	Sex (% Female)	PA Measure	Findings
					Support (standardized β = 0.01) at 8th grade had indirect effects on PA at 8th grade through Perceived Barriers. The total effect of Self-Efficacy was standardized β = 0.14. Lagged associations for these variables were not reported. This model did not differ among these races. The model differences with Asian and Native American respondents were not reported.
Both Sexes, One Race					
Taveras 2007[208] n = 10856 Follow-up: 4 years	10 to 15	White (93%)	59%	Self-Report (Weekly frequency)	White Boys and Girls: This study had a large sample and therefore showed significant, but not clinically relevant, results. Generally, a one-hour increase in television-viewing per week or in total sedentary behavior was associated with a 0.02 to 0.05 hour increase in MVPA per week over one year of follow-up. This association was similar for boys and for girls.
Dearth-Wesley 2012[191] n = 353 Follow-up: 2 to 4 years	6 – 9 at baseline	Chinese	47%	Self-Report (Weekly frequency)	Asian Boys and Girls: At baseline, children with highly active mothers had 3.6 [CI: 1.1 to 11.4] greater odds of being highly active. However, this association was not observed at follow-up (OR = 0.9, CI: 0.3 to 2.9). These associations did not differ by sex.
Butte 2014[185] n = 282 Follow-up: 2 years	8 to 10	Hispanic	53%	Accelerometer (3 day, Hip worn ActiCal)	Hispanic Boys and Girls: Father's age (unstandardized β = -0.05, p = 0.02), mother's education (unstandardized β = -0.10, p = 0.04), child's time-varying pubertal status (unstandardized β = -0.83, p = 0.06) and mother's change in BMI (unstandardized β = -0.18, p = 0.004) negatively predicted percent of time spent in MVPA over 2 year follow-up for boys and girls. Previous percent of time in MVPA predicted current percent of time in MVPA at both time points (unstandardized β = 0.40 and 0.17, p = 0.0001 and 0.02). Hispanic Boys: Time varying BMI negatively predicted percent of time spent in MVPA for boys (unstandardized β = -0.22, p = 0.0002). This association was not seen among girls.
One Sex, One Race					
Davison 2007[190]	11	White	100%	Accelerometer	White Girls:

Table A3: Longitudinal Studies that examine determinants of physical activity (PA) in unique subgroups defined by sex and race					
Study	Age (Baseline)	Races	Sex (% Female)	PA Measure	Findings
n = 168 Follow-up: 2 years				(7 day, Hip worn ActiGraph)	Earlier pubertal development significantly predicted direct and indirect paths to lower PA at two year follow-up. The standardized β for the direct path was 0.19. The indirect paths showed that earlier pubertal development predicted lower self-worth (standardized β = -0.22), higher depression (standardized β = 0.23) and higher maturity fears (standardized β = 0.22) at 2 year follow-up. Lower self-worth, higher depression and higher maturity fears in turn predicted lower enjoyment of PA (standardized βs -0.16 to -0.33), which in turn predicted lower PA (standardized βs 0.21 to 0.24).
Davison 2009[189] n = 174 Follow-up: 6 years	9 at baseline	White	100%	Accelerometer (7 day, Hip worn ActiGraph)	White Girls: This analysis compared trajectories of parent modeling, peer support and parent logistic support between girls who maintained PA from 9 to 15 years compared to girls who did not. For girls who maintained PA over follow-up, logistic support was constant compared to girls who did not maintain PA, where logistic support decreased. Girls who maintained PA had consistently higher parent modeling than girls who did not maintain PA. No effect was found for peer support. Previous PA was consistently higher among girls who maintained PA at age 13 to 15; however, the associations were not always statistically significant.

Appendix B: Minne-Loppet Treatment Effect Estimates in All Strata of Sex and Ethnicity/Race

Table B1: Treatment Effect Estimates on Self-Determination Theory Constructs Stratified by Sex

	Females: Treatment Effect (Beta [95%CI])	*Males: Treatment Effect (Beta [95%CI])*
Exercise Motivation[a]	0.26 [-0.78 to 1.29]	-0.01 [-0.91 to 0.89]
Ski Motivation[a]	0.76 [-0.3 to 1.82]	1.2 [0.17 to 2.22][d]
Autonomy[b]	-0.09 [-1.53 to 1.35]	0.42 [-0.95 to 1.79]
Competence[c]	0.62 [-0.42 to 1.67]	0.89 [-0.02 to 1.79]
Relatedness[c]	0.96 [-0.29 to 2.2]	0.34 [-0.76 to 1.44]

[a]Range of possible scores for the motivation scales are 4 to 20

[b]Range of possible scores for the autonomy scale is 6 to 30

[c]Range of possible scores for the competence and relatedness scales are 5 to 25

[d]Minne-Loppet arm differs significantly from control arm at $p < 0.05$

Table B2: Treatment Effect Estimates on Self-Determination Theory Constructs Stratified by Ethnicity/Race

	African American: Treatment Effect (Beta [95%CI])	Hispanic: Treatment Effect (Beta [95%CI])	White: Treatment Effect (Beta [95%CI])	Mixed or Other: Treatment Effect (Beta [95%CI])
Exercise Motivation[a]	1.08 [0.03 to 2.14][a]	-0.02 [-1.76 to 1.72]	0.92 [-2.07 to 3.91]	-1.1 [-2.43 to 0.22]
Ski Motivation[a]	1.51 [0.18 to 2.85][a]	1.48 [0.18 to 2.79][d]	0.1 [-2.28 to 2.47]	-0.14 [-1.65 to 1.38]
Autonomy[b]	1.01 [-0.46 to 2.47]	-1.17 [-3.47 to 1.14]	-0.39 [-3.08 to 2.3]	0.49 [-1.59 to 2.56]
Competence[c]	1.95 [0.91 to 2.99][d]	-0.14 [-1.69 to 1.42]	0.63 [-0.94 to 2.19]	-0.19 [-1.64 to 1.26]
Relatedness[c]	1.21 [-0.27 to 2.69]	0.93 [-0.51 to 2.37]	0.41 [-1.9 to 2.71]	0.08 [-1.69 to 1.84]

[a]Range of possible scores for the motivation scales are 4 to 20

[b]Range of possible scores for the autonomy scale is 6 to 30

[c]Range of possible scores for the competence and relatedness scales are 5 to 25

[a]Minne-Loppet arm differs significantly from control arm at $p < 0.05$